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THE EFFECTS OF TWO VELOCITIES OF ISOKINETIC TRAINING ON ISOLATED MUSCULAR PERFORMANCE CHARACTERISTICS

by

J. R. SEXSMITH

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
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(Supervisor)

E Wendy Bedingfield

Murray K Smith

David Magee

Date: 28.8.85

DEDICATION

TO MY PARENTS

Thanks for your continual support and instilling me with the desire, patience, perserverence and pride to successfully achieve this goal.

ABSTRACT

Thirty male subjects (22.9 ± 0.6 yrs; 75.5 ± 1.6 kg; 183.1 ± 1.3 cm) were divided into three experimental groups to study the effects of two selected velocities of isokinetic resistance training upon the force, velocity and time characteristics of three isolated muscular performances. One group trained at high velocities (HVG), the second trained at a low velocity (LVG), with the third group acting as a control (CONG). Isokinetic knee extension (IKE) and plantar flexion (IPF) were trained at a 1.0 rad·s^{-1} velocity for the LVG while the HVG trained at 5.0 and 4.0 rad·s^{-1}, respectively, for the two movements. Training consisted of 3 sets of 20 seconds work:40 seconds recovery, 4 times per week for 5 weeks for both groups. At commencement of the study the three groups were matched with respect to the height of rise of center of mass (HTRCM) on the criterion isolated vertical block jump task (VBJ).

Quantitative analyses were done pre and post training on the IKE and IPF performances at seven preselected velocities utilizing a Cybex II isokinetic dynamometer. Cinematographic and force platform techniques were applied to the VBJ performance with selected kinetic, kinematic and temporal variables being assessed. No physiologically significant difference were noted among the three groups on the IKE, IPF or VBJ performance variables on the pre training assessment.

The quantified descriptions of the three performances provided information previously unavailable from the literature. Data for the kinetic, kinematic and temporal variables of the VBJ performance were similar to those reported in the literature for subjects of similar skill level.

Low velocity IKE training was found to significantly elevate both the force-velocity and power-velocity curves across all velocities, while enhancements for the HVG were restricted to the high velocity portion of those curves. A similar effect was noted from the IPF training, however, the enhancements were limited to the velocity at which the training occurred. Although significant increases in torque and power production were achieved from the two isokinetic training programs, no alterations occurred in the VBJ performance. No pre to post differences were noted for any of the IKE, IPF or VBJ performance variables in the CONG. The results support the concepts of a specificity of velocity as well as a specificity of movement pattern training effect. The underlying physiological mechanisms responsible appear to be neuromuscular in origin, probably centering around the pattern and synchronization of motor unit recruitment within these movements.

Although the performances assessed were closely related in terms of the muscle groups being utilized, the lack of relationship between the characteristic parameters of the two modes of performance indicates their independence and supports the importance which neural factors appear to have in resistance training and skilled performance.

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INTRODUCTION

The ability to generate and coordinate large amounts of force from the muscles of the lower body over a short period of time to produce maximal velocity of the centre of mass is critical to successful performance in numerous athletic events. These relationships are particularly typified by the performance of elite athletes in skilled impulse movements, such as sprinting and jumping. Efforts to characterize, explain and through training enhance such impulse performances have been initiated by researchers in the areas of biomechanics and exercise physiology.

Cinematographical (Miller and East, 1976; Hubley and Wells, 1983), force platform (Luhtanen and Komi, 1978; Bosco and Komi, 1979a; Tihanyi, 1984) and electromyographical (Oka et al., 1976) techniques have been utilized to describe and quantify some of the force-time characteristics of various skilled impulse performances. While such techniques are valuable for isolating and quantifying the force-time components of muscular performance, they have been used sparingly for interpreting the underlying neuromuscular mechanisms (Komi and Bosco, 1977; Hubley and Wells, 1983; Hudson and Owen, 1983), or elucidating the effects which specific training programs (Rosentswieg and Hinson, 1972; Tihanyi, 1984; Wiater et al., 1984) have had upon impulse performances.

Furthermore, although numerous studies exist describing complex performances such as the long jump (Luhtanen and Komi, 1979), high jump (Viitasalo and Aura, 1984) and the volleyball spike jump (Oka et al., 1976; Samson and Roy, 1976; Coutts, 1982), little has been done to isolate and quantify the temporal relationships of simple impulse movements like the stationary volleyball block jump. Those few reports which do exist on this movement (Coutts, 1978a,b; Adrian and Laughlin, 1983) are of limited value due to the variety of methodologies used, small sample size and the variability noted in the obtained results.

Progressive resistance training programs involving plyometrics, traditional free-weight exercises, constant resistance, variable resistance or isokinetic equipment have demonstrated inconsistent and variable results in terms of effects upon isolated muscular and skilled impulse performances (Chui, 1950; Berger, 1962a,b, 1963; Pipes and Wilmore, 1975; Pipes, 1978; Blattner and Noble, 1979; Stevens, 1980; Clutch et al., 1983). Successful performance has been found to be related to the force-velocity and power-velocity characteristics of skeletal muscle (Moffroid and Whipple, 1970; Pipes and Wilmore, 1975; Perrine et al., 1978; Gregor et al., 1979; Miyashita and Kanehisa, 1979; Sale and MacDougall, 1981). Isokinetic dynamometers allow muscular contractions to be isolated, controlled and quantified at any selected point along the force-velocity curve (Thistle et al., 1967; Moffroid and Kusiak, 1975; Perrine and Edgerton, 1978; Wickiewicz et al., 1984).

Studies utilizing isokinetic training programs have often reported conflicting results which in many cases appear due to the variability amongst the experimental designs used. The majority of these studies have focused upon comparing isokinetic training to other training modes (DeLateur et al., 1972; Pipes and Wilmore, 1975; Smith and Melton, 1981) or the physiological adaptations arising from the applied isokinetic training program (Gettman et al., 1978; Costill et al., 1979; MacDougall et al., 1979, 1980). Objective ascertainment of the effects of isokinetic dynamometer training upon either isolated muscular (Lesmes et al., 1978; Caiozzo et al., 1981; Coyle et al., 1981; Kanehisa and Miyashita, 1983) or skilled impulse performance (Wiater et al., 1984) has been minimal, especially at the higher angular velocities which would approach those observed during impulse performances. Inconclusive results have arisen from such studies, especially with respect to the effects of training velocity upon both the force- and power-velocity characteristics of the musculature (Adeyanju et al., 1983; Vitti, 1984) and skilled performances

(Pipes and Wilmore, 1975; VanOteghen, 1975; Wilmore, 1979; Smith and Melton, 1981; Shields et al., 1985). These results may be due to design factors, measurement and analysis techniques as well as the low training velocities used.

With these points in mind, the purposes of this study re:

1. to isolate, characterize, and quantify two single-joint muscular contractions (knee extension and plantar flexion) and one skilled muscular impulse performance (a controlled, stationary volleyball block jump);
2. to quantitatively evaluate the effects of two specific velocities of isokinetic dynamometer training for the isolated knee extensor and plantar flexor muscle groups upon those three performances; and
3. to assess the relationships between selected physiological and biomechanical characteristics of those three performances.

METHODOLOGY

EXPERIMENTAL DESIGN

In order to study the effects of two selected velocities of isokinetic resistance training on the force, velocity and time characteristics of three isolated muscular performances in adult males, three experimental groups were formed. Two groups were exposed to isokinetic training programs with one group designated to train at high velocities (HVG) and the other at a low velocity (LVG). The third group acted as a control (CONG). The basic design of the experiment is outlined in Table 1.

TABLE 1. Experimental design.

	Group		
	HVG	LVG	CONG
Subjects per Group	10	10	10
Training Velocity ($rad \cdot s^{-1}$)			
Plantar Flexion	4.0	1.0	--
Knee Extension	5.0	1.0	--
Training Regimen			
Work Time (s) per Set	20	20	--
Rest Between Sets (s)	40	40	--
Sets per Session	3	3	--
Sessions per Week	4	4	--
Duration (Weeks)	5	5	5

The criterion muscular performances selected for quantitative analysis were:

1. controlled, isokinetic knee extension (IKE);
2. controlled, isokinetic plantar flexion (IPF); and
3. an isolated standing vertical jump (a controlled volleyball block jump - VBJ).

SUBJECTS

Thirty university age male volunteers were used as subjects. Their age, height and mass (mean ± SEM) were 22.9 ± 0.6 yrs., 183.1 ± 1.3 cm and 75.5 ± 1.6 kg, respectively at the commencement of the project.

The subjects were chosen from the entire volunteer population (n=43) based upon the criteria listed below.

Within the past three years they must:

1. have participated regularly in and trained for some type of sport,
2. not have been actively engaged in a regular training program specifically designed for, or have regularly participated in, a sport in which vertical jumping was a major component, and
3. not have had any significant injury (ie. requiring surgery and/or prolonged rehabilitation) to the musculature or joint of either the knees or ankles.

Informed consent was obtained from each subject after the purpose of the study and all testing and training procedures had been explained.

Initially, thirty-six subjects met the above criteria and chose to commence participation in the project. During the week prior to the initial testing session all subjects participated in a familiarization session for both IKE and IPF on the isokinetic dynamometer and received an orientation to all the testing and training procedures. The subjects were assigned to one of three groups: control (CONG), low velocity training (LVG), or high velocity training (HVG). This was done using a serpentine method to equate the groups (n=12 per group) on the criterion variable the height of rise of centre of mass (HTRCM). The HTRCM determined from the results obtained on the initial VBJ testing session with the mean HTRCM for the three groups being HVG = 48.54, LVG = 48.34 and CONG = 48.32 cm.

During the course of the study, six subjects withdrew (two per group) due to personal reasons or through injuries sustained in external sporting activities. Thus, the study was completed with ten subjects in each group.

VARIABLE SELECTION

After reviewing the literature, the dependent variables listed below were chosen as being indicative physiological and biomechanical parameters for characterizing and quantifying muscular function in the three criterion performances.

A. Physical Characteristics

Mass (MASS). Mass of the subject's body in kg.

Lean body mass (LBM). Estimated fat free mass of the subject in kg.

Percent body fat (PBF). Estimated proportion of the subject's body composed of stored fat.

B. Isolated Isokinetic Knee Extension and Plantar Flexion

Relative peak torque (RPT). The maximal torque generated during the extension movement irrespective of joint position expressed relative to body mass ($Nm\cdot kg^{-1}$).

Relative peak power (RPP). The maximal instantaneous power output generated during the extension movement irrespective of joint position expressed relative to body mass ($Nm\cdot kg^{-1}\cdot s^{-1}$).

C. Isolated Vertical Block Jump - Cinematography

Height of rise of the centre of mass (HTRCM). The maximal vertical displacement in cm of the centre of mass calculated as the greatest Y coordinate for the centre of mass during the VBJ minus the Y coordinate of the centre of mass for the standardized standing position in frame one.

Vertical velocity at take-off (VELTO). Calculated from adjacent digitized frames as the vertical velocity of the centre of mass in $m\cdot s^{-1}$ at the point of take-off.

Ground force (GFOR). The maximal vertical ground force generated during the loading phase of the VBJ as calculated from the vertical velocity of the centre of mass data, expressed in N.

Minimum angle (MA). The smallest angle, in radians, which occurred at a joint during execution of the VBJ.

Mean angular velocity (MAV). Calculated as the average velocity, in rad·s^{-1}, of a joint from the point in time where MA occurred through to the point of take-off.

Mean angular velocity time (MAVT). The time in seconds from the point in time where MA occurred to the point of take-off.

Maximal angular velocity (VMX). Calculated from adjacent digitized frames as the greatest velocity, in rad·s^{-1}, attained by a joint from the point in time where MA occurred through to the point of take-off.

D. Isolated Vertical Block Jump - Force Platform

First negative impulse (FNI). That portion of the force-time integration below the body weight line and above the ground reaction force curve which occurred during the initial unweighting phase of the VBJ, expressed in N·s.

First negative impulse time (FNIT). The time interval, in seconds, of the FNI.

Positive impulse (PI). That portion of the force-time integration above the body weight line and below the ground reaction force curve which occurred during the loading phase of the VBJ, expressed in N·s.

Positive impulse time (PIT). The time interval, in seconds, of the PI.

Second negative impulse (SNI). That portion of the force-time integration below the body weight line and above the ground reaction force curve which occurred during the final unweighting phase of the VBJ, expressed in N·s.

Second negative impulse time (SNIT). The time interval, in seconds, of the SNI.

Total positive impulse (TPI). Calculated as the force-time integration of body weight from initiation of the FNI through to the point of take-off subtracted from the force-time integration of the VBJ ground reaction force over the identical time frame, expressed in N·s.

Total positive impulse time (TPIT). The time interval, in seconds, of the TPI.

Minimum ground reaction force (FMIN). The minimum vertical force recorded during the unweighting phase of the VBJ, expressed in N.

Time of minimum ground reaction force (TFMIN). The time in seconds prior to the point of take-off when the FMIN occurred.

Maximal ground reaction force (FMAX). The maximal vertical force recorded during the loading phase of the VBJ, expressed in N.

Time of maximal ground reaction force (TFMAX). The time in seconds prior to the point of take-off when the FMAX occurred.

E. Explanation of Variable Notations

The following prefixes and suffixes were used in conjunction with the previously indicated variable notations to clarify the specific characteristics of the variables as measured in this study.

H Refers to the hip joint.

K Refers to the knee joint

A Refers to the ankle joint.

0, 0.5, 1, 2, 3, 4, or 5 Refers to the angular velocity setting in rad·s^{-1} at which the torque generating capabilities of the knee and ankle extensors were tested on the isokinetic dynamometer.

PRE Refers to the initial testing session.

POST Refers to the testing session which occurred after completion of the training program.

DIFF Refers to the resultant created by subtracting the PRE value from the POST value for a variable.

TRAINING REGIMEN

The subjects in the high velocity and low velocity groups completed a progressive resistance isokinetic training program for plantar flexion - dorsiflexion and knee extension-flexion movements using the Cybex II isokinetic dynamometer system as set up for the testing sessions. The HVG trained at angular velocities of 4.0 rad$\cdot$s^{-1} for plantar flexion - dorsiflexion and 5.0 rad$\cdot$s^{-1} for knee extension-flexion. The LVG performed all training at an angular velocity of 1.0 rad$\cdot$s^{-1}. For all subjects the ranges of motion were through at least 0.9 and 1.6 radians to complete extension for the plantar flexion and knee extension movements respectively. Both the right and left limbs were trained separately, with the initial training limb altered for each successive training session. For all sessions the knee extension-flexion training was done first. The calibration of the isokinetic dynamometer recording system was verified and adjusted if required prior to, halfway through, and at the end of each training day.

Table 1 outlines the design of the training program for both the high velocity and low velocity groups. The resistance training program was designed to be similar in intensity, frequency and duration to those which athletes involved in 'jumping' sports might have been prescribed at the start of a competitive season. The program consisted of three sets of each exercise done on a 1:2 work-recovery ratio with the work interval being 20 seconds.

The two training groups were equated with respect to the work interval and therefore the total training time for each of the muscle groups. The number of contractions done per 20 second exercise bout were 11 and 6 for the LVG, and 40 and 24 for the HVG, for plantar flexion and knee extension respectively. Small differences occurred in the number of contractions done within the groups due to the variability between subjects in the range of motion executed when performing the movements.

The subjects trained at approximately the same time of day, four days per week for a duration of five weeks resulting in 20 total training sessions. To ensure all criteria were met, the researcher monitored all training sessions. The subjects received feedback in terms of the peak torque output attained upon completion of each work bout. Verbal motivation was provided by the researcher during each training session.

At the end of the third week of the training program, the subjects from the CONG group repeated the testing procedure in order to maintain familiarity with the IKE and IPF movements.

Subjects in all three groups were requested to maintain their normal daily activity and dietary patterns and not to engage in any form of jumping or additional lower body resistance training throughout the duration of the study. The participants were required to submit weekly activity records.

DATA COLLECTION AND ANALYSIS

The physiological and biomechanical performance assessments detailed below were administered to all subjects between 48 and 72 hours prior to the initiation of, and after the completion of, the training program. The sequence, equipment and methodology for both the pre and post testing sessions were the same for all individuals. To avoid potential circadian effects, both testing sessions were conducted as closely as possible to the same time schedule.

A. Physical Characteristics

Body mass was determined to the nearest 0.1 kg using a Health-o-Meter scale. Lean body mass and percent body fat were estimated from the determination of body density through the underwater weighing technique according to the formula of Brozek et al. (1963). The residual volume was estimated as 25% of the measured, underwater vital capacity.

B. Isolated Isokinetic Knee Extension and Plantar Flexion

The force-velocity relationship of the isolated knee extensor and plantar flexor muscle groups were measured utilizing the Cybex II isokinetic dynamometer system (Lumex Inc.). Both the IKE and IPF performances were measured on the right limb at seven preselected velocities. These velocities were 0.0, 0.5, 1.0, 2.0, 3.0, 4.0 and 5.0 rad·s^{-1}. To minimize potential order and motivational effects across trials, the order of presentation commenced with the 3.0 rad·s^{-1} velocity setting for all subjects and was then randomized. However, the presentation sequence for each individual was identical on the pre and post tests. All measurements, except for the 0.0 rad·s^{-1} velocity, consisted of one trial which commenced with the flexion movement from the anatomical neutral position and continued through four attempted maximal extensions. The RPT and RPP values were determined from the extension movement on which the greatest deflection was observed. The anatomical neutral position (0.0 rad·s^{-1}) was defined as full extension for the knee joint and as the position where the dorsal surface of the foot was perpendicular to the tibial line for the ankle. Measurements for the 0.0 rad·s^{-1} velocity consisted of two trials at a preset angle of 1.57 rad for IKE and 0.0 rad for IPF. A minimum of 30 seconds rest was given between each trial. The IKE angle of 1.57 rad was chosen for evaluation as this angle has been suggested as the position from which the extension movement should commence in order to optimize performance of the VBJ (Scates, 1972; Canadian Volleyball Association, 1978; Bratton and Lefroy, 1980). The IKE was evaluated first with a minimum of 5 minutes rest allowed prior to the IPF test. All subjects were encouraged to passively stretch the involved muscle groups prior to the testing. When performing each trial, the subjects were verbally encouraged to exert maximally.

Slight modifications were made to the standard IKE and IPF testing protocols (Lumex Inc., 1980) to maximize isolation of the muscle groups being evaluated while minimizing potential artifacts arising from excessive b[illegible]y movement. The test set-up as modified for the IKE and IPF respectively are illustrated in Figures 1 and 2. It should be noted that while two isokinetic dynamometers were used for the training sessions only one dynamometer, the same one, was used for collecting data from the pre and post training test sessions. For the IKE evaluations, the second dynamometer was used to stabilize the left leg with the knee at the 1.57 rad position. Joint alignment and length of the lever arm were standardized within each subject for all testing and training sessions. The measurements were recorded at a chart speed of 25 $\mathrm{mm \cdot s^{-1}}$ with the damping set at [illegible] while the torque scale was adjusted to provide the largest tracing. In all cases the settings were identical within subjects for both testing sessions. The Cybex recording system was calibrated before each testing session according to the procedures outlined by Lumex

Figure 1-Experimental set-up utilized for isokinetic knee extension, illustrating the muscle group isolation protocol and posture employed by each subject.

Figure 2-Experimental set-up utilized for isokinetic plantar flexion, illustrating the muscle group isolation protocol and posture employed by each subject.

Inc. (1980). The calibration was checked after every tenth subject and was found to remain constant.

The resultant tracings of the IKE and IPF force-time curves were placed onto a Bendix digitizing board (Model 2425520) hardwired via a Hewlett-Packard 9864A Digitizer to a Hewlett-Packard 9825A computer. A computer program was written which calculated directly the previously mentioned dependent variables from the digitized tracing. When the first peak of the force-time trace was identified as an overshoot artifact due to acceleration within the limb-lever system (Sapega et al., 1982) it was excluded from the analysis.

C. Isolated Vertical Block Jump - Cinematography

The angular displacements of the body segments during the isolated standing vertical jump were recorded cinematographically using a Photo-Sonic[illegible]PL 16mm camera. In order to determine frame rate and synchronize the data from the force platform and film for analysis, a Photo-Sonics Series TLG neon timing light generator set at 10 Hz was connected to both the Honeywell-Visicorder system and the Photo-Sonics camera. The camera was operated at 100 frames per second with an f-stop of 2.2 and shutter angle of 1.047 radians resulting in an exposure time of 0.00167 s. Kodak Ektachrome 7250 film (400 ASA) was used and pushed one full f-stop when developed.

The camera was aligned in the subject's frontal plane at a distance of 29.70 m from the centre of the force platform. A reference tree was positioned posteriorly in the subject's mid-saggital plane 80 cm from the centre of the force platform for the duration of the filming. To ensure maximum visibility of the segmental endpoints all subjects performed the VBJ dressed only in an athletic supporter with a black curtain used as a background. The placement of the equipment for the VBJ testing sessions is shown in Figure 3.

In order to standardize the vertical jump performance, isolate the movement to the vertical axis, and obtain a sport related movement pattern, the subjects performed a controlled volleyball block jump. Standardization and control were achieved by limiting the arm swing and providing a target upon which the subjects visually focused throughout the entire VBJ movement. The arm swing was limited by having the hands held initially at head height and allowing arm movement only in the frontal plane. These procedures reduced the contribution of the arm and head segments to the forces summating to elicit maximum take-off velocity and thereby increased the relative contribution from the knee extensor and plantar flexor muscle groups to the VBJ performance (Luhtanen and Komi, 1978). The subjects performed one warm-up jump followed by two maximal VBJ trials.

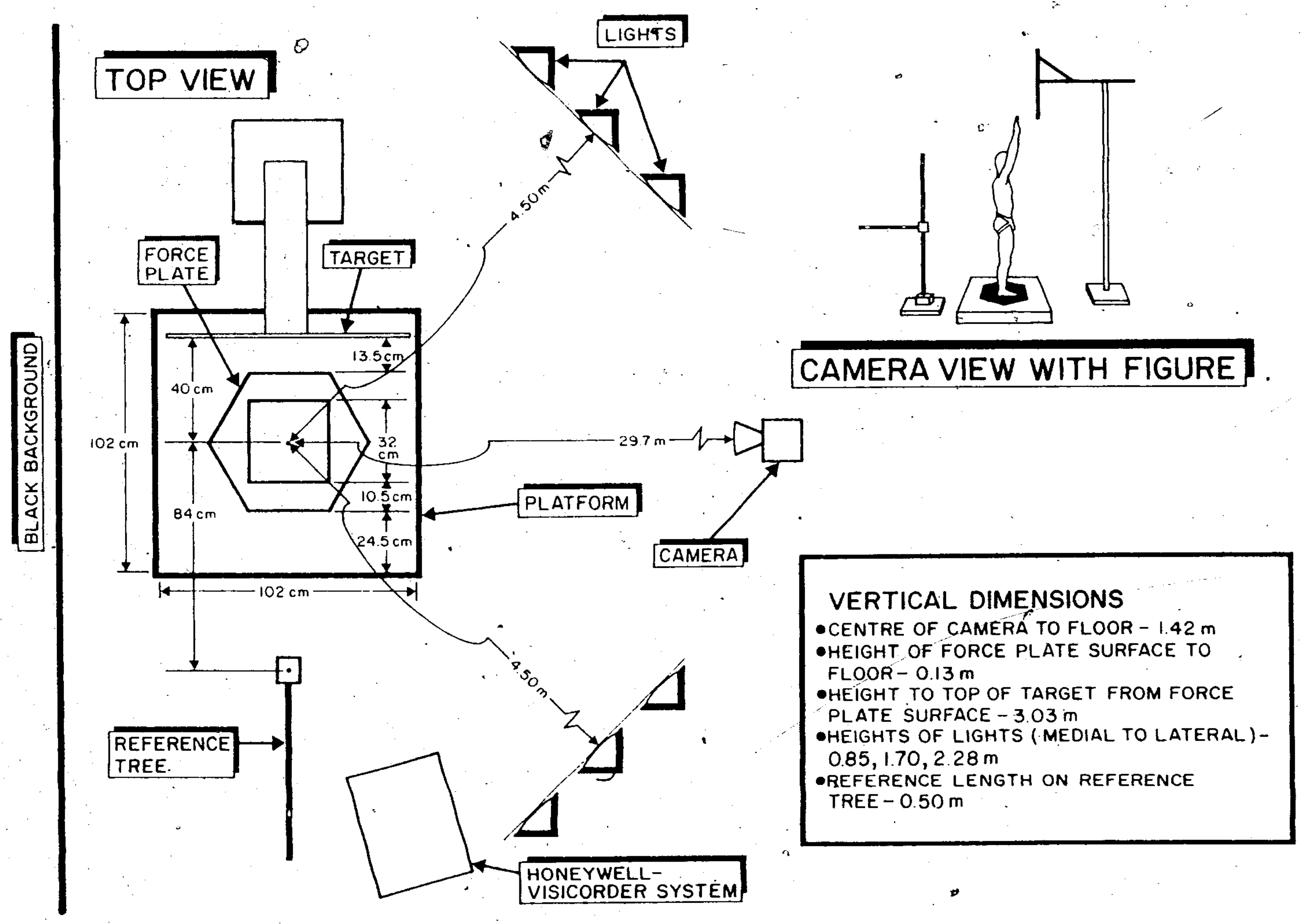

Figure 3-Physical layout of equipment for the vertical block jump testing sessions.

Trials were repeated if the aforementioned criteria were not met or if excessive rotation occurred about the vertical axis. All subjects were encouraged to passively stretch the muscle groups involved prior to the testing.

The datafilm was projected by a pin registered Traid VR-100 film analyzer at a magnification of 62.5X onto the Bendix digitizing board for determination of body segment coordinates utilizing the previously described digitizing system. A computer program was developed to calculate each subject's centre of mass coordinates based upon a fourteen segmental moment model technique. The segmental weights and centres of mass location were based upon Humanscale 1/2/3 data (Diffrient et al., 1974). The program also calculated the angular kinematic variables for the hip, knee and ankle joints as well as the linear and angular velocities from the raw segmental endpoint data. Eleven segmental endpoints from the head, trunk and right limbs were digitized in each frame of film analyzed. As shown in the pilot project, the isolation of the VBJ in the frontal plane coupled with the symmetrical nature of the movement allowed for the reduction of the number of endpoints digitized without compromising the data.

To determine which VBJ trial would be used for analysis, the successful trials for each subject were assessed to determine the height of rise of the centre of mass.

The trial with the greatest HTRCM was used for the subsequent complete analysis. All trials were sampled at a frequency of 33.3 Hz with 46 frames being analyzed per trial. In all cases frame 32 was identified as the moment of take-off from the force plate. Frame 1 was a reference frame in which the subject was standing erect with both arms fully extended vertically. The number of frames analyzed allowed for complete execution of the VBJ movement from the initial starting position through the counter-movement and take-off phases to at least 0.12 s past the height of rise of the centre of mass for all subjects. The raw kinematic data (excluding frame 1) was smoothed at a cut-off frequency of 5 Hz using a second order Butterworth low-pass recursive digital filter procedure (Patrick et al., 1980; Pezzack et al., 1977).

Digitizing reliability was determined through a test-retest digitizing procedure using both the x and y coordinates derived from the 11 segmental endpoints on one randomly selected frame per trial. For the 60 trials analyzed the test-retest reliability coefficients ranged from 0.99981 to 0.99999.

D. Isolated Vertical Block Jump - Force Platform

The force-time characteristics of the isolated standing vertical jump were recorded from a Stoelting Force Sensitive Platform (Cat. No. 19570) connected to a Honeywell Electronic Medical System (Model No. 6793478-1). The force platform signals were generated through linear variable differential transformers (LVDT's) with the force vectors being measured only in the vertical axis as the VBJ criterion performance was isolated to this axis. The generated signals were amplified by the Honeywell system, displayed visually on an oscilloscope (Model 8011), with a permanent trace produced by a Model 1912 Ultraviolet Visicorder onto Kodak Linagraph paper (Type 2022 Direct Print) at a speed of 200 $mm \cdot s^{-1}$. A standardized static calibration of the force platform was done prior to testing and after every fifteenth subject. The calibration was found to be linear and constant.

The resultant tracings of the force-time curves which corresponded to the assessed cinematographical trial were analyzed utilizing the previously described digitizing system. A computer program was written which calculated directly the previously mentioned dependent variables from the digitized trace.

E. Computer Programs

The various computer programs used for the digitizing analyses were written in whole or in part by several individuals, including the author, associated with the Biomechanics Laboratory at the University of Alberta, Edmonton, Alberta. They are available upon request from the author.

STATISTICAL ANALYSIS

A one-way analysis of variance (Winer, 1971) was used to compare the group means of the previously listed dependent variables from the initial testing session to determine if any group differences existed prior to application of the training program. In order to assess the effects of the training program, a one-way analysis of variance was performed on the group means of the differential values (post minus pre) for each dependent variable. In both instances a Scheffe multiple comparison of means post hoc procedure (Winer, 1971) was used to locate significant differences between pairs of means. In all cases, an alpha level equal to or less than five percent ($p \leq 0.05$) was required for the acceptance of a significant difference between means.

To assess the relationship between the force, velocity and time characteristics of the criterion muscular performances, correlations were determined between the dependent variables as measured in the initial testing session by the Pearson product-moment technique (Winer, 1971). The significance probability of the correlations was calculated using a t-test for correlation coefficients of dependent samples (Ferguson, 1976). In order to protect the overall alpha level at $p \leq 0.05$ given the number of dependent variables of interest and the sample size, the Bonferroni technique (Morrison, 1976; Morris, 1980) was applied to adjust the critical r value appropriately.

All analysis of variance, Scheffe, Pearson product-moment correlation and t-test procedures were conducted utilizing the Statistical Analysis Systems software package (SAS Institute, 1982).

RESULTS

The results are presented under the following six headings: Physical Characteristics, Training Regimen, Isolated Isokinetic Knee Extension and Plantar Flexion, Isolated Vertical Block Jump - Cinematography, Isolated Vertical Block Jump - Force Platform, and Relationships Between Selected Variables. Group means with the standard error of the mean are tabulated and/or graphed. The raw data for all subjects are recorded in Tables 12 through 23, Appendix D. Summaries of the statistical analyses (Analysis of variance tables, Scheffe multiple comparison of means, Pearson product-moment correlation matrix with t-probabilities) are contained in Appendix E, Tables 24 through 138.

PHYSICAL CHARACTERISTICS

Table 2 contains the group means for descriptive physical characteristics of the subjects prior to and after completion of the training program. No significant differences (Tables 24, 25, 27 and 29, Appendix D) were noted between the three groups for any of the characteristics prior to commencement of the study. No significant alterations were noted either between or within groups after

TABLE 2. Physical characteristics of the three groups ($\overline{x}$ ± SEM):

Variable	HVG	LVG	CONG.
AGE (yrs)	23.0 ± 0.8	21.8 ± 1.3	23.9 ± 0.6
BODY MASS (kg)			
Pre	75.0 ± 2.9	74.7 ± 2.6	76.1 ± 2.9
Post	74.8 ± 2.5	74.8 ± 2.6	75.8 ± 3.0
LEAN BODY MASS (kg)			
Pre	66.7 ± 2.2	65.9 ± 2.3	65.9 ± 1.7
Post	66.7 ± 2.0	66.2 ± 2.2	65.6 ± 1.8
PERCENT BODY FAT (%)			
Pre	10.8 ± 1.6	11.8 ± 1.2	13.0 ± 1.5
Post	10.2 ± 1.4	11.3 ± 1.3	13.1 ± 1.5

* Significantly different ($p \leq 0.05$) from CONG
§ Significantly different ($p \leq 0.05$) from LVG

application of the training program (Tables 26, 28 and 30, Appendix E). Complete data for each group on these parameters is contained in Table 12, Appendix D.

TRAINING REGIMEN

The activity profiles for all subjects are located in Table 11, Appendix C. The activity summaries suggest that there were no dramatic alterations in the mode and volume of physical activity engaged in by the subjects in all three groups immediately prior to and throughout the study.

Subject adherence to the training program was excellent with three subjects in both the LVG and HVG missing one training session each. All CONG subjects attended the mid-training program maintenance familiarization session.

ISOLATED ISOKINETIC KNEE EXTENSION AND PLANTAR FLEXION

Complete data on the relative peak torques and relative peak powers of the three groups for both IKE and IPF may be found in Tables 13 through 16, Appendix D. The statistical analyses are summarized in Tables 31 through 82, Appendix E. The results of the training program upon IKE and IPF are illustrated graphically in Figures 4 through 7 with the data expressed as the percentage difference between the pre and post training means within each group.

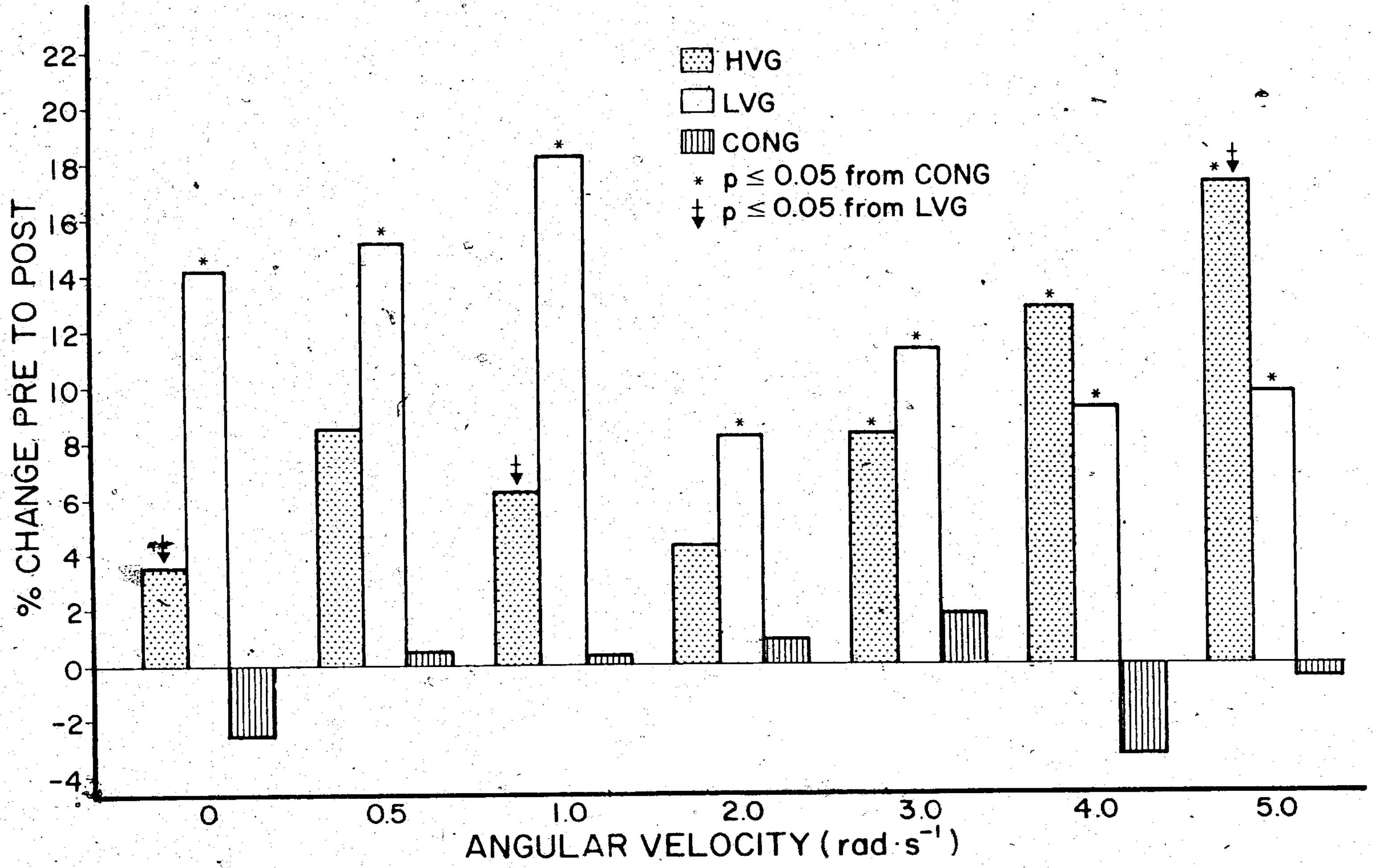

Figure 4-Percentage changes in relative peak torque of the knee extensors in the three groups after training.

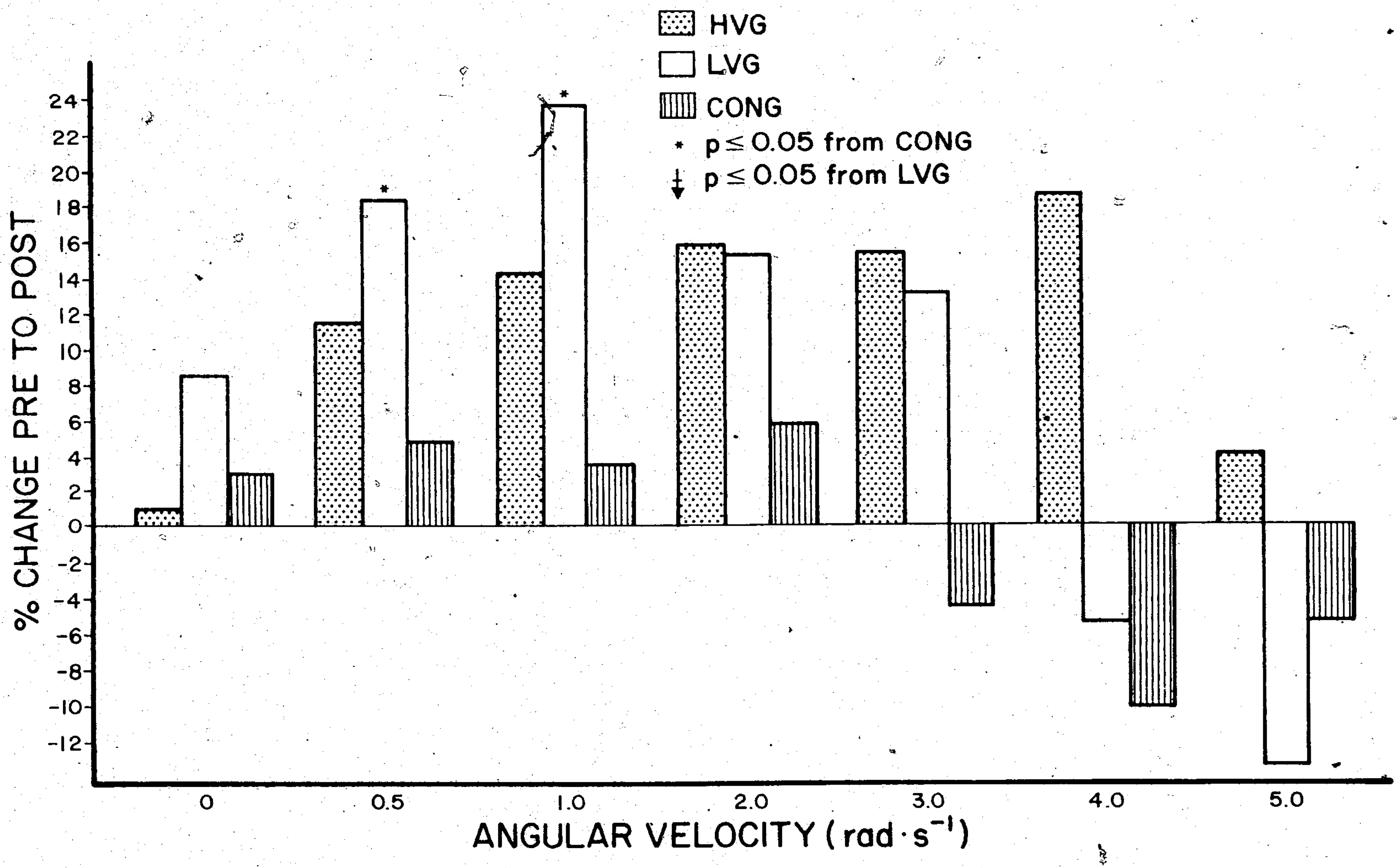

Figure. 5-Percentage changes in relative peak torque of the plantar flexors in the three groups after training.

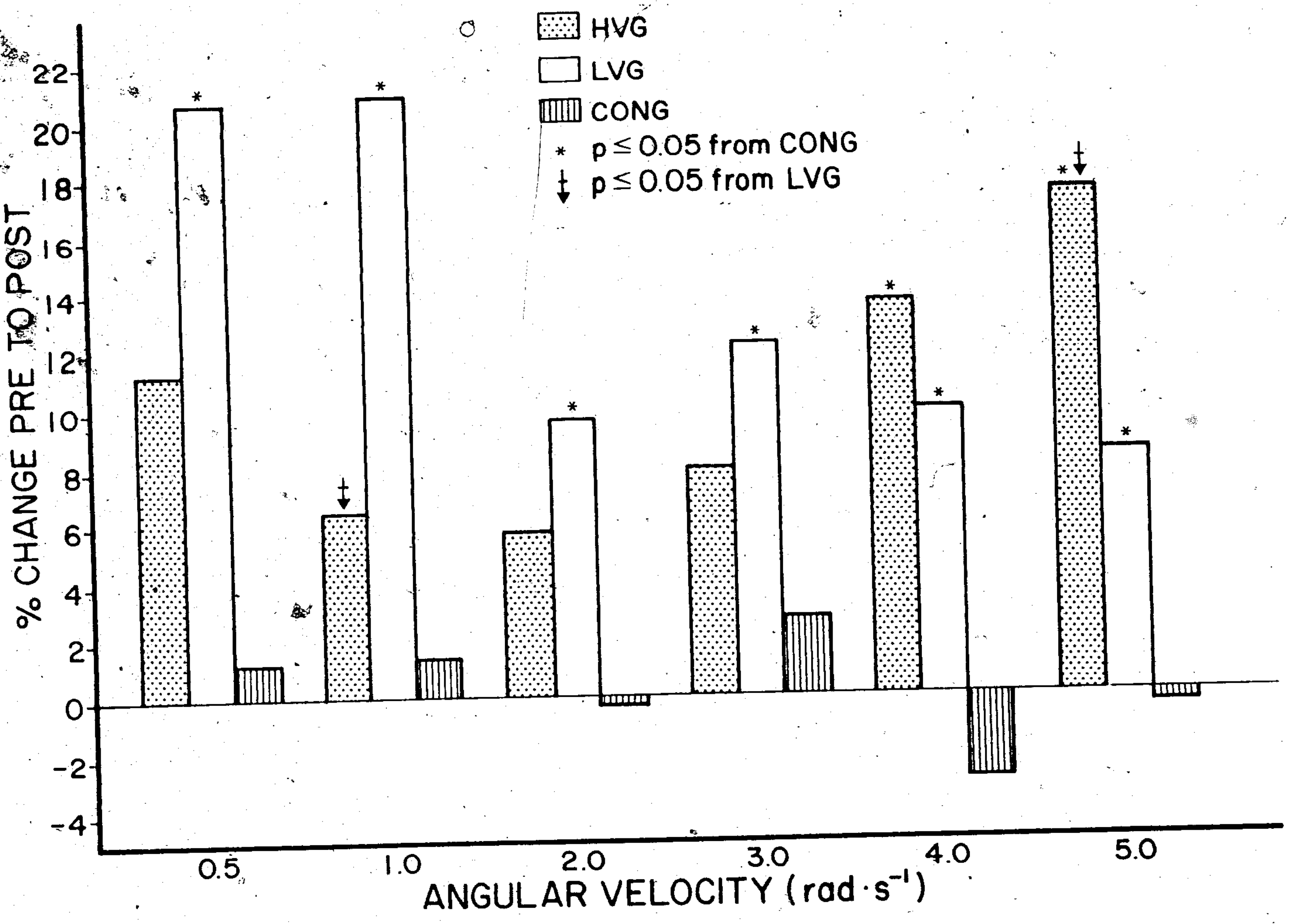

Figure 6-Percentage changes in relative peak power of the knee extensors in the three groups after training.

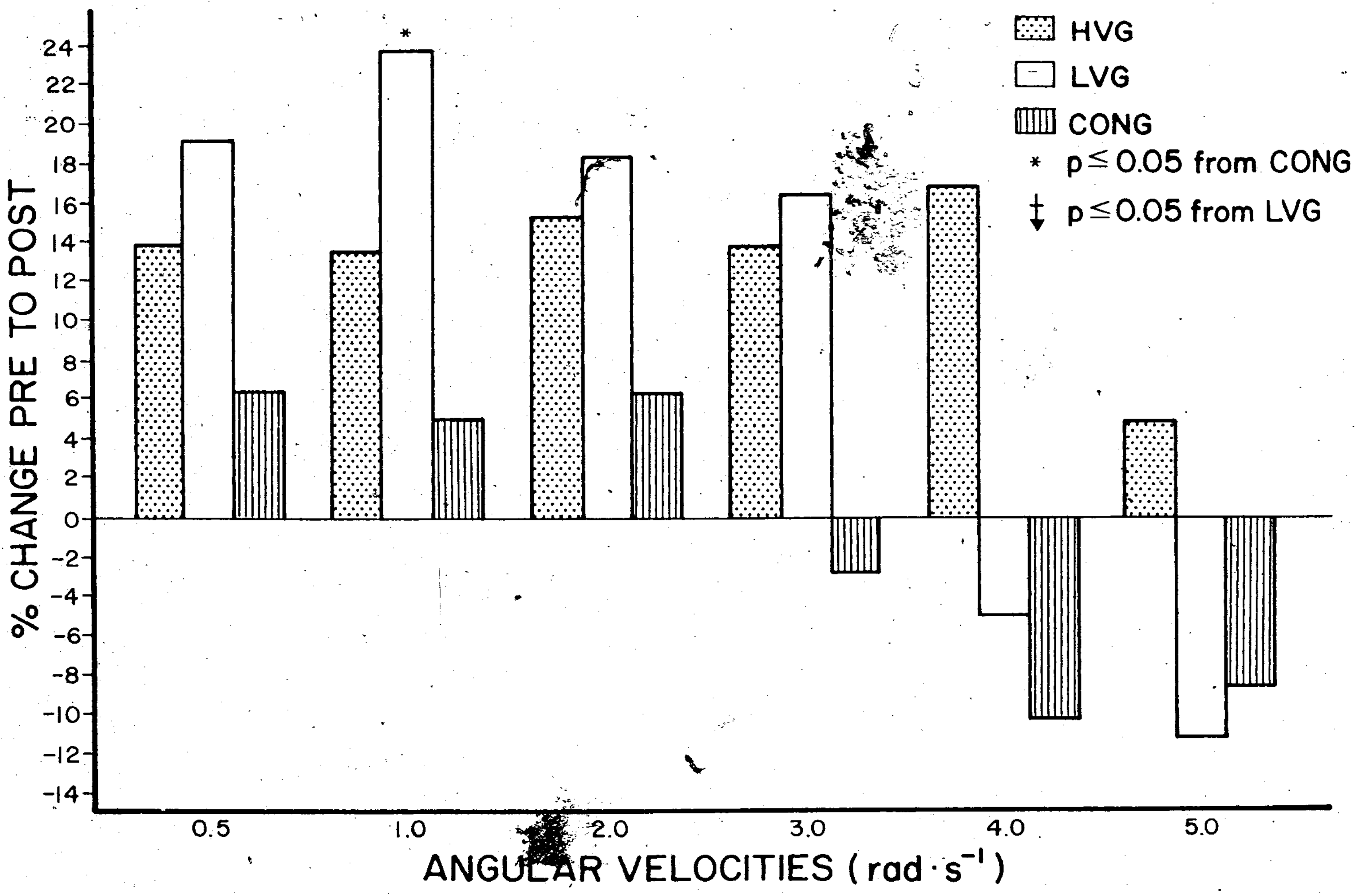

Figure 7-Percentage changes in relative peak power of the plantar flexors in the three groups after training.

No significant differences were noted between the groups at any velocity for knee extension prior to application of the training program (Tables 31 to 37 and 59 to 64, Appendix E). Similar results were evident for plantar flexion except for the 3.0 rad$\cdot$s^{-1} velocity (Tables 45 to 51 and 71 to 76, Appendix E). At this velocity, both the relative peak torque and power of the ankle plantar flexors were significantly lower for the control group (Tables 49 and 74, Appendix E).

Significant increases in force generation for knee extension were noted in both the HVG and LVG after application of the training program (Tables 38 through 44, Appendix E). No differences were noted at any velocity within the control group. As evidenced in Figure 4, the training resulted in an increase across all velocities for the LVG with the greatest enhancement occurring at the 1.0, 0.5 and 0.0 rad$\cdot$s^{-1} velocities. The HVG demonstrated significant increases only at the 3.0, 4.0 and 5.0 rad$\cdot$s^{-1} velocities. A comparison between the two training groups revealed that the relative peak torque generated by the HVG on the post test was significantly lower than the LVG at velocities of 1.0 and 0.0 rad$\cdot$s^{-1}, however it was significantly higher at the 5.0 rad$\cdot$s^{-1} velocity.

Similar results were noted with respect to the relative peak power production of the knee extensor muscle group (Tables 65 to 70, Appendix E and Figure 6). At all velocities, the CONG group demonstrated no change. Significant increases were seen at all velocities for the LVG after training with the most pronounced effects arising at 0.5 and 1.0 rad·s^{-1}. Only at the fastest two velocities, 4.0 and 5.0 rad·s^{-1}, were increases attributable to training noted in the HVG. The LVG demonstrated a significantly higher relative peak power than the HVG at 1.0 rad·s^{-1} with the converse occurring at the 5.0 rad·s^{-1} velocity.

Significant pre to post training effects were noted for relative peak torque of the plantar flexors at three velocities: 0.5, 1.0 and 4.0 rad·s^{-1} (Tables 52 to 58, Appendix E). As illustrated in Figure 5, at the 0.5 and 1.0 rad·s^{-1} velocities only the LVG demonstrated a significant increase with training. The analysis of variance also revealed a significant difference at the 4.0 rad·s^{-1} velocity, however, the post hoc analysis failed to reveal which group means were different (Table 57, Appendix E).

The effects of training upon the relative peak power output of the plantar flexors is shown in Figure 7. The statistical analyses (Table 77 to 82, Appendix E) identified only one training related alteration, that being an increase for the LVG at the 1.0 rad·s^{-1} velocity. Again, a difference was shown at the 4.0 rad·s^{-1} velocity but the location of the difference remained unidentified (Table

81, Appendix E).

ISOLATED VERTICAL BLOCK JUMP - CINEMATOGRAPHY

The raw data from the cinematographical analysis of the VBJ is located in Tables 17 through 21, Appendix D. Tables 83 to 112 in Appendix E summarize the statistical analyses for the chosen kinetic and kinematic variables. The pre and post training means for the three groups are presented in Tables 3 and 4.

There were no significant differences between the three groups on any of the VBJ measured variables prior to commencement of the training program. The training program did not result in any significant alterations in 14 of the 15 variables studied within the three groups, including the HTRCM criterion performance variable. The one difference was noted in the HVG where a significant pre to post decrease was seen for the mean angular velocity of the hip.

ISOLATED VERTICAL BLOCK JUMP - FORCE PLATFORM

Tables 22 and 23 (Appendix D) contain the raw data from the force platform analysis of the pre and post training VBJ performances. Summaries of the statistical analysis for the selected impulse characteristics are presented in Tables 113 through 136, Appendix E. The pre and post training means for the three groups are presented in Tables

TABLE 3. Cinematographically assessed kinetic and kinematic characteristics for the three groups on the isolated vertical block jump ($\bar{x}$ ± SEM).

Variable	Group		
	HVG	LVG	CONG
HTRCM (cm)			
Pre	48.54 ± 1.16	48.34 ± 1.47	48.33 ± 1.91
Post	48.90 ± 1.23	47.53 ± 1.46	48.83 ± 1.39
VELTO ($m.s^{-1}$)			
Pre	2.84 ± 0.05	2.76 ± 0.06	2.82 ± 0.08
Post	2.78 ± 0.05	2.73 ± 0.06	2.80 ± 0.06
GFOR (Nm)			
Pre	1246.36 ± 59.29	1144.22 ± 87.95	1194.15 ± 71.34
Post	1286.61 ± 83.90	1171.80 ± 78.55	1320.22 ± 89.07
MAH (rad)			
Pre	1.47 ± 0.09	1.38 ± 0.06	1.47 ± 0.07
Post	1.47 ± 0.10	1.46 ± 0.05	1.53 ± 0.07
MAK (rad)			
Pre	1.38 ± 0.06	1.29 ± 0.07	1.35 ± 0.04
Post	1.43 ± 0.07	1.30 ± 0.07	1.41 ± 0.04
MAA (rad)			
Pre	1.46 ± 0.04	1.41 ± 0.04	1.41 ± 0.02
Post	1.50 ± 0.04	1.39 ± 0.04	1.41 ± 0.03

* Significantly different ($p \leq 0.05$) from CONG
§ Significantly different ($p \leq 0.05$) from LVG

TABLE 4. Cinematographically assessed angular kinematic characteristics for the three groups on the isolated vertical block jump performance ($\bar{x}$ ± SEM).

Variable	Group		
	HVG	LVG	CONG
MAVH (rad·s^{-1})			
Pre	4.80 ± 0.19	4.92 ± 0.15	4.65 ± 0.11
Post	4.48 ± 0.16*§	5.05 ± 0.18	4.80 ± 0.13
MAVTH (s)			
Pre	0.28 ± 0.01	0.29 ± 0.01	0.29 ± 0.01
Post	0.28 ± 0.01	0.29 ± 0.01	0.27 ± 0.01
VMXH (rad·s^{-1})			
Pre	8.94 ± 0.34	9.58 ± 0.28	9.09 ± 0.25
Post	9.01 ± 0.47	9.50 ± 0.24	9.17 ± 0.33
MAVK (rad·s^{-1})			
Pre	6.15 ± 0.34	5.80 ± 0.24	6.11 ± 0.31
Post	5.86 ± 0.21	5.93 ± 0.15	6.15 ± 0.25
MAVTK (s)			
Pre	0.23 ± 0.01	0.26 ± 0.02	0.24 ± 0.02
Post	0.23 ± 0.01	0.26 ± 0.01	0.23 ± 0.01
VMXK (rad·s^{-1})			
Pre	11.87 ± 0.31	11.94 ± 0.32	11.77 ± 0.23
Post	11.53 ± 0.40	12.12 ± 0.26	12.01 ± 0.22
MAVA (rad·s^{-1})			
Pre	4.62 ± 0.40	3.96 ± 0.38	4.63 ± 0.32
Post	4.05 ± 0.35	4.24 ± 0.35	4.32 ± 0.19
MAVTA (s)			
Pre	0.22 ± 0.02	0.27 ± 0.03	0.22 ± 0.02
Post	0.23 ± 0.02	0.25 ± 0.02	0.23 ± 0.01
VMXA (rad·s^{-1})			
Pre	9.25 ± 0.42	9.15 ± 0.30	9.33 ± 0.19
Post	8.38 ± 0.42	9.37 ± 0.33	8.91 ± 0.21

* Significantly different ($p \leq 0.05$) from CONG

§ Significantly different ($p \leq 0.05$) from LVG

5 and 6.

There were no significant differences between the HVG, LVG and CONG on any of the measured variables before the start of the training program. For the three groups, no significant changes were noted in any of the selected impulse characteristics due to the training program. Figure 8 provides an illustration of the force-time curve and impulse characteristics of the VBJ performance utilizing the mean pre training data from the LVG.

RELATIONSHIPS BETWEEN SELECTED VARIABLES

The Pearson product-moment correlations matrix for the dependent variables measured in the initial testing session is presented in Table 137, Appendix E. Application of the Bonferroni technique to retain the experimentwise error rate at $p \leq 0.05$ resulted in a critical value of $r > 0.647$ being required for acceptance of a significant correlation. Within both the isokinetic dynamometer and VBJ performances, significant correlations were found only between variables which exhibited prima facie commonality. Therefore, high correlations were seen between such groups of variables as the different velocities assessed at a given joint within the isokinetic performances. However, there were no significant correlations of note between the isokinetic dynamometer and VBJ performances.

In conjunction with the identification provided by,

TABLE 5. Force platform assessed impulse characteristics of the three groups for the isolated vertical block jump performance ($\bar{X}$ ± SEM).

Variable	Group		
	HVG	LVG	CONG
FNI (N·s)			
Pre	76.51 ± 6.83	71.75 ± 7.26	80.34 ± 6.20
Post	71.20 ± 8.29	74.40 ± 4.71	76.76 ± 4.00
FNIT (s)			
Pre	0.35 ± 0.03	0.40 ± 0.03	0.35 ± 0.03
Post	0.31 ± 0.03	0.36 ± 0.03	0.34 ± 0.03
PI (N·s)			
Pre	210.60 ± 10.36	223.48 ± 9.41	227.73 ± 10.61
Post	233.11 ± 12.19	214.54 ± 9.30	238.06 ± 15.89
PIT (s)			
Pre	0.39 ± 0.03	0.42 ± 0.03	0.41 ± 0.02
Post	0.38 ± 0.03	0.41 ± 0.02	0.37 ± 0.02
SNI (N·s)			
Pre	13.47 ± 1.36	13.43 ± 1.20	13.26 ± 1.15
Post	12.61 ± 1.22	14.74 ± 1.23	12.78 ± 1.22
SNIT (s)			
Pre	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00
Post	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00
TPI (N·s)			
Pre	175.78 ± 7.85	185.15 ± 13.78	182.90 ± 11.91
Post	184.10 ± 9.24	177.61 ± 7.28	179.48 ± 7.76
TPIT (s)			
Pre	0.76 ± 0.05	0.85 ± 0.04	0.78 ± 0.05
Post	0.72 ± 0.05	0.80 ± 0.04	0.74 ± 0.04

* Significantly different ($p \leq 0.05$) from CONG
§ Significantly different ($p \leq 0.05$) from LVG

TABLE 6. Force platform assessed kinetic characteristics of the three groups for the isolated vertical block jump performance ($\bar{X}$ ± SEM).

Variable	Group		
	HVG	LVG	CONG
FMIN (N)			
Pre	301.75 ± 43.27	363.17 ± 48.89	236.18 ± 69.25
Post	287.23 ± 63.92	309.42 ± 43.17	245.76 ± 66.27
TFMIN (s)			
Pre	0.54 ± 0.04	0.61 ± 0.04	0.58 ± 0.05
Post	0.52 ± 0.04	0.56 ± 0.03	0.51 ± 0.04
FMAX (N)			
Pre	1788.08 ± 62.11	1784.84 ± 109.90	1798.19 ± 76.30
Post	1872.77 ± 70.04	1757.93 ± 76.20	1872.81 ± 91.13
TFMAX (s)			
Pre	0.21 ± 0.02	0.19 ± 0.02	0.20 ± 0.02
Post	0.21 ± 0.02	0.23 ± 0.02	0.22 ± 0.01

* Significantly different ($p \leq 0.05$) from CONG

§ Significantly different ($p \leq 0.05$) from LVG

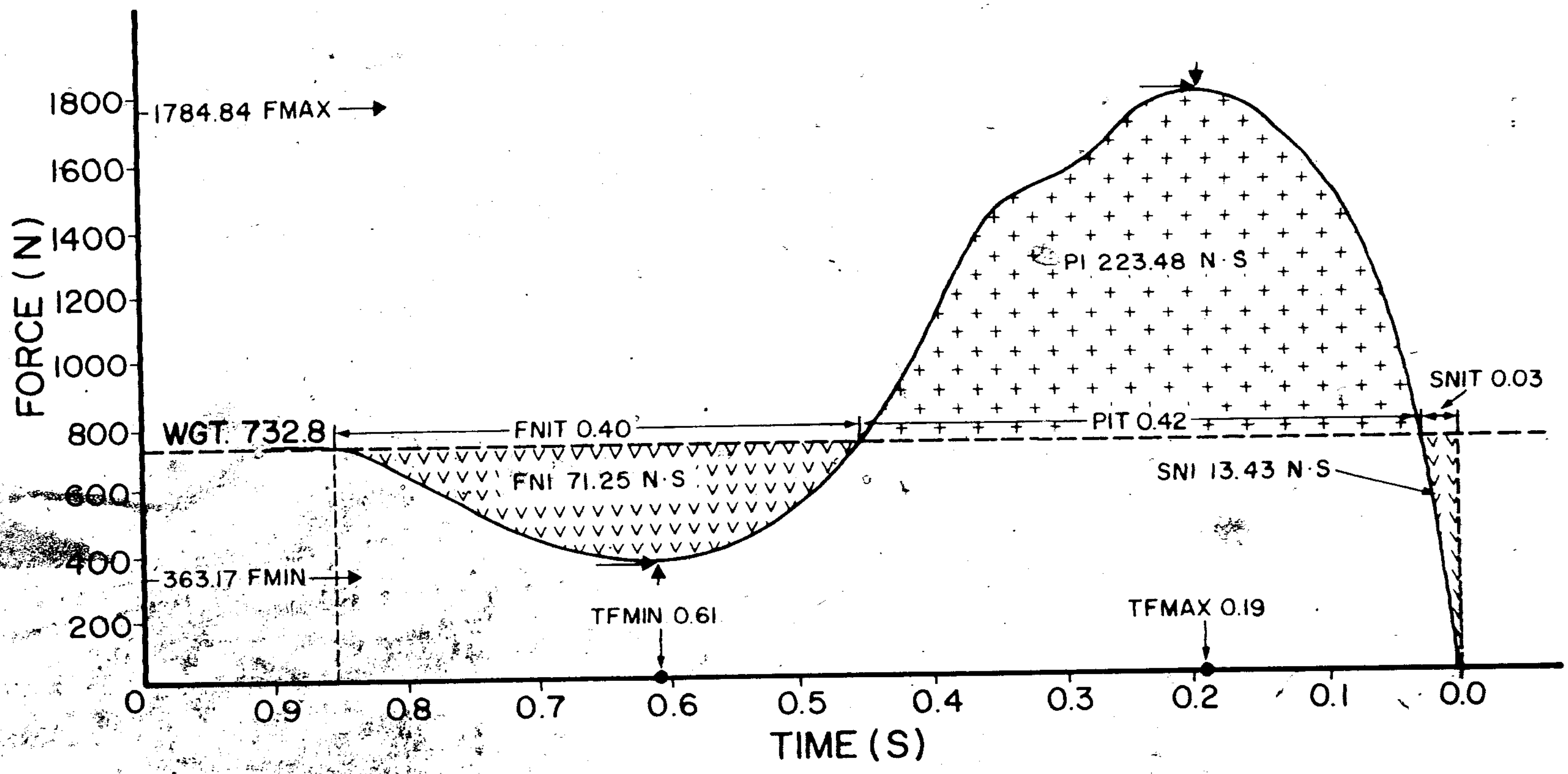

Figure 8. The force-time curve and impulse characteristics for the low velocity group prior to training.

the initial correlational assessment, 24 key variables were selected for their theoretical relatedness to the successful optimization of the criterion performances. The intercorrelations amongst these variables are shown in Table 138, Appendix E. Table 7 summarizes the correlations ($p \leq 0.05$, $r \geq 0.355$) of note between the isokinetic (IKE and IPF) and VBJ performances.

TABLE 7. A summary of the significant correlations between the isokinetic (IKE and IPF) and VBJ performances.

Variable	Correlated with	r value*
HTRCM	VELTO	.8838
	MAH	-.4386
	PI	.4327
	KRPT3	.3751
	KRPT5	.5079
	ARPT1	.3698
VELTO	PI	.3917
	MAH	-.4001
	KRPT3	.4330
	KRPT5	.4606
FMAX	MASS	.4813
	GFORCE	.5943
	MAVK	.4812
	PI	.4886
	TPI	.6981
TPI	MASS	.5091
	PI	.3968
	MAK	-.5377
	MAVTK	.3589
KRPT0	MAH	.3615
	MAVTH	.3861
	ARPT1	.3554
ARPT0	MAH	-.4666
ARPT1	MAH	-.4319
ARPT4	MAH	-.4405

* Significant correlation at ≤ 0.05, $r \geq 0.355$

DISCUSSION

The discussion is prese[illegible] under the following six headings: Physical Charac[illegible]tics, Training Regimen, Isolated Isokinetic Knee Extension and Plantar Flexion, Isolated Vertical Block Jump, Relationships Between Selected Variables, and Summary and Conclusions. Tables 8 and 10 provide comparative data from studies which have addressed either isokinetic training or training for a standing vertical jump performance and have been included to assist with the interpretation of results from the present study.

PHYSICAL CHARACTERISTICS

The physical characteristics of the three groups were similar to those expected for a young, athletic adult male population. While the three groups were equated on the criterion variable HTRCM, it was found that they were also similar with respect to all physical characteristics measured at the commencement of the study.

No alterations to body mass, lean body mass or percent body fat were found after completion of the isokinetic training program. These results are consistent with studies of similar, or longer, training duration and subject population (Lesmes et al., 1978; Coyle et al., 1981; Petersen et al., 1984). Further clarification is hindered as the majority of the isokinetic training research has not explored this relationship (Johnson, 1980; Caiozzo et al., 1981; Kanehisa and Miyashita, 1983; Jenkins et al., 1984; Vitti, 1984). When body composition changes have been noted from isokinetic training programs, they have occurred from programs of longer duration which involved exercises for all the major muscle groups of the body (Pipes and Wilmore, 1975; Gettman et al., 1978; Gettman et al., 1980).

TRAINING REGIMEN

The purpose of the training regimen was to further quantify the isokinetic training stimuli by attempting to create groups which were both distinct and equitable thus providing for a clearer understanding of the effects produced by isokinetic training programs. Also addressed was the specificity of training principle in terms of movement velocity within the limits of the currently available and commonly utilized modes of resistance training. These purposes appear to have been achieved. The two experimental groups undertook training which was identical in mode and muscle involvement but distinct in training velocity. A type of equality was achieved through the use of identical work intervals and consequently total training time for both groups. As evident in Table 8 this approach to equating training volume, or a similar strategy of proportionally adjusting the number of contractions as the movement velocity increases, has been used previously (Moffroid and Whipple, 1970; Kanehisa and Miyashita, 1983; Vitti, 1984).

Resistance training programs have been consistently undertaken with the assumption that the effects garnered from such endeavors would enhance athletic performance. Attempts to optimize this implied relationship have led to the design of numerous types of resistance overload apparatus including those which stabilize the body and isolate a specific muscle group. A quantified assessment of these assumptions was achieved through designing the training program to use an apparatus (Cybex II isokinetic dynamometer) which progressively overloaded in an isolated mode those muscle groups which have been shown as major contributors to a specific skilled performance (Luthanen and Komi, 1978; Hubley and Well, 1983). As well, several authors have indicated that optimal training effects with respect to enhancing a skilled performance should occur when the specificity of training principle is applied to the movement velocity of the muscle groups being trained (Pipes and Wilmore, 1975; Counsilman, 1976; Sale and Mac-

TABLE 8. Comparataive data on the effects of isokinetic training at various velocities on torque production by the knee extensors.

Author	Year	Training Velocity (rad·s^{-1})	Percent Change in Knee Extension Torque at Selected Test Velocities (rad·s^{-1})^{a,b}							Training Volume^{c}			Subjects			
			0.0	0.5	1.0	2.0	3.0	4.0	5.0	I	F	D	Age (yrs)	Sex	N per Group	Training Status^{d}
Moffroid et al.	1969	0.39	14*	11*	....	....	....	....	....	1:30c	5	4	18-31	M/F	20	S;M
Moffroid and Whipple	1970	0.63	18.8	31.8*	10.5	7.9	....	....	....	1:120s	3-4	6	adult	M/F	10	S;M
		1.88	16.7	19.6*	11.6	15.9	....	....	....	1:120s	3-4	6	adult	M/F	10	S;M
		Con	10.3	6.2	6.6	2.0	....	....	....	Con	---	6	adult	M/F	10	S;M
Pipes and Wilmore^{e}	1975	0.42	20.6*	30.2*	....	33.7*	....	....	....	3:8c	3	8	20-38	M	9	....
		2.37	21.5*	24.1*	....	53.6*	....	....	....	3:15c	3	8	20-38	M	9	....
		Con	-3.7	-1.3	....	-0.3	....	....	....	Con	---	8	20-38	M	9	....
Lesmes et al.^{f}	1978	3.14	11.0*	....	14.2*	16.2*	13.6*	n.s.	n.s.	10:6s+ 2:30s	4	7	23.6	M	5	....
Johnson	1980	0.52	....	27*	....	15*	12	....	....	3:8c	3	6	17-24	F	10	....
		3.14	....	11	....	14*	14	....	....	3:16c	3	6	17-24	F	10	....
		Con	....	2	....	-3	-1	....	....	Con	---	6	17-24	F	10	....
Caiozzo et al.^{e}	1981	1.68	14.7*	....	14.2*	7.8*	7.9*	5.5*	0.5	2:10c	3	4	20-38	M/F	5	S;M
		4.19	0.4	....	4.6	5.9*	6.6*	8.8*	4.2	2:10c	3	4	20-38	M/F	5	S;M
		Con	2.2	....	2.9	2.2	1.7	0.7	1.2	Con	---	4	20-38	M/F	7	S;M
Coyle et al.	1981	1.05	20.3*	....	31.8*	....	9.2*	....	0.9	5:6c	3	6	25.1	M	4	A;M
		5.24	23.6*	....	15.1*	....	16.8*	....	18.5*	5:12c	3	6	25.0	M	4	A;M
		1.05+5.24	18.9*	....	23.6*	....	7.9*	....	16.1*	3:6+12c	3	6	22.3	M	4	A;M
		Con	-1.5	....	-2.3	....	-0.7	....	-1.5	Con	---	6	26.9	M	5	A;M
Smith and Melton	1981	.5+1+1.5	0.5	....	21.3	....	....	24.7	....	3:50%	3	6	16-18	M	3	T+A;P
		3+4+5	6.7	....	3.4	....	....	60.9	....	3:50%	3	6	16-18	M	3	T+A;P
		Con	3.7	....	0.9	....	....	-3.1	....	Con	---	6	16-18	M	3	T+A;P
Kanehisa and Miyashita^{g}	1983	1.05	....	....	22.4*	15.8*	6.9*	7.6*	7.8*	3:10c	6	8	24.1	M	8	....
		3.14	....	....	15.1*	14.5*	19.4*	21.1*	21.4*	3:30c	6	8	23.6	M	8	....
		5.24	....	....	-1.6	-2.1	6.8	17.2*	20.0*	3:50c	6	8	23.0	M	5	....
		Con	....	....	-2.8	0.1	-0.3	2.0	-3.3	Con	---	8	22.6	M	8	....

TABLE 8. Comparative data on the effects of isokinetic training at various velocities on torque production by the knee extensors (continued).

Author	Year	Training Velocity (rad·s^{-1})	Percent Change in Knee Extension Torque at Selected Test Velocities (rad·s^{-1})[a,b] 0.0	0.5	1.0	2.0	3.0	4.0	5.0	Training Volume[c] I	F	D	Subjects Age (yrs)	Sex	N per Group	Training Status[d]
Jenkins et al.	1984	1.05	....	6.0	15.1*	....	8.1*	4.8*	18.9	1:15c	3	6	22-33	M/F	12	....
		4.19	....	6.3*	7.5*	....	7.6*	7.2*	9.8*	1:15c	3	6	22-33	M/F	12	....
Petersèn et al.	1984	3.14	....	-6.0*	....	....	8.4*	....	....	4-6:20s	4	5	18.8	M	12	T;M
Vitti	1984	1-2.5	....	....	8,9	....	....	12.3*	....	4:30s	3	6	<30	M	9	S-A;....
		3.5-5	....	....	2.0	....	....	13.9*	....	4:30s	3	6	<30	M	10	S-A;....
		1-5	....	....	2.4	....	....	13.2*	....	4:30s	3	6	<30	M	9	S-A;....
		Con	....	....	-5.4	....	....	6.2	....	Con	---	6	<30	M	10	S-A;P
Sexsmith (present study)	1985	1.0	14.7*	15.3*	18.2*	8.3*	11.3*	9.3*	10.0*	3:20s	4	5	21.8	M	10	T;M
		5.0	3.6	8.6	6.3	4.3	8.3*	12.8*	17.3*	3:20s	4	5	23.0	M	10	T;M
		Con	-2.6	0.6	0.3	0.8	1.9	3.3	0.7	Con	---	5	23.9	M	10	T;M
Sexsmith[h] (present study)	1985	1.0	8.6	18.4*	23.6*	15.1	13.1	-5.4	-11.5	3:20s	4	5	21.8	M	10	T;M
		4.0	0.8	11.0	14.3	15.7	15.3	18.4*	4.2	3:20s	4	5	23.0	M	10	T;M
		Con	3.2	4.7	3.5	5.7	-4.6	-10.3	-5.6	Con	---	5	23.9	M	10	T;M

[a] Reported results have been taken to the nearest velocity.

[b] An * indicates that the reported difference was significant; Con indicates a group which did not train isokinetically; .... indicates no measurement reported at that velocity; n.s. indicates result reported as being non-significant.

[c] I indicates intensity as a number of sets and a number of contractions per set (c) or a number of sets and a duration in seconds per set (s) or as a percentage of the initial peak torque which demarcated the cessation point of a continuous bout (%); F indicates frequency as days per week; D indicates duration in weeks.

[d] S = sedentary; A = active recreationally; T = trained athlete; M = maintenance of pre isokinetic training program activity level (S, A or T) throughout the study; P = prohibition of all other forms of training for duration of study.

[e] Data reported under 2.0 rad·s^{-1} column was measured at 2.51 rad·s^{-1}.

[f] Same subjects used and data reported in Costill et al., 1979.

[g] Reported measurement was maximal knee extension power.

[h] Data is for peak torque of the plantar flexors.

Dougall, 1981; Grimby, 1982). With these points in mind the training regimen design approximated a velocity commonly prescribed for athletic training programs and approached the mean angular joint velocity for a skilled performance within the limitations of the isokinetic equipment. For this study, these training velocities were, respectively, 1.0 and 5.0 rad$\cdot$s^{-1} for the knee extensors and 1.0 and 4.0 rad$\cdot$s^{-1} for the plantar flexors. These selected velocities were labeled low and high with respect to the limitations of the isokinetic device (max 5.24 rad$\cdot$s^{-1}).

As evident from Table 8, numerous researchers have reported 'low' training velocities of 1.05 rad$\cdot$s^{-1} or less for IKE (Moffroid and Whipple, 1970; Pipes and Wilmore, 1975; VanOteghen, 1975; Johnson, 1980; Coyle et al., 1981; Kanehisa and Miyashita, 1983; Jenkins et al., 1984). However, only Coyle et al. (1981) and Kanehisa and Miyashita (1983) have used a high velocity (5.24 rad$\cdot$s^{-1}) as a distinct training stimulus. Several authors have reported the use of 'high' training velocities which were in fact substantially lower in absolute terms (3.14 to 1.6 rad$\cdot$s^{-1}) (Moffroid and Whipple, 1979; Pipes and Wilmore, 1975; VanOteghen, 1975; Adeyanju et al., 1983; Johnson, 1980; Petersen et al., 1984) and/or unquantified (VanOteghen, 1975; Blattner and Noble, 1979; Stevens, 1980; Wathen, 1980; Wiater, 1984). Others have combined several velocities within a single training group (Smith and Melton, 1981; Vitti, 1984) or superimposed concurrent modes of training (VanOteghen, 1975; Stevens, 1980; Wathen, 1980) which has obfuscated interpretation of the effects reported. No studies have been found in the literature involving IPF training.

One of the important design aspects of this study was the elimination of specific concurrent training programs which may have contributed to the enhancement of the muscle groups primarily involved with the criterion skilled performance. At the same time, to allow for comparison and application of the results to an athletic population, the subjects were chosen based upon their involvement in non-jumping sports and were directed to maintain this involvement throughout the duration of the study. A review of the activity profiles indicates that this was achieved (Table 11, Appendix C). There were no major differences between the three groups with respect to activity levels either prior to or throughout the program. Also, no dramatic changes in activity levels occurred within any group during the training program. This observation is supported by the pre to post training consistency found for the physical characteristics of the subjects. As illustrated in Tables 8 and 10, few studies have followed such an approach. Very few studies have used athletically trained subjects and those which have are of limited interpretive value due to having superimposed similar neuromuscular training (Thorstensson et al., 1976; Stevens, 1980; Wathen, 1980; Clutch et al., 1983; Viitasalo and Aura, 1984). Only two studies have utilized isokinetic training with athletic subjects in an effort to establish the effects of the training upon skilled performance. Unfortunately, the results of VanOteghen (1975) are clouded by the aforementioned factor, while those of Melton and Smith (1981) suffer from an inadequate number of subjects for statistical analysis.

ISOLATED ISOKINETIC KNEE EXTENSION AND PLANTAR FLEXION

Although the groups were equated based upon the HTRCM criterion performance, the control and experimental groups were found to be equal with respect to all force and power measurements across the velocities tested at the outset of the study. The lone exception noted was that of IPF torque and power output at 3.0 rad·s^{-1} where the control group values were slightly lower. Further observation suggested that this finding was more of an anomaly than one with a physiological basis which would affect interpretation of any training results (see Table 15, Appendix D, Subject 24).

The IKE force-velocity curve was found to rise in a slightly curvilinear manner with decreasing velocity, plateauing at 0.5 rad·s^{-1}. The response pattern was similar, with the magnitude of the torque values being greater or equal, to those reported previously (Gregor et al., 1979; Caiozzo et al., 1981; Yates and Kamon, 1983; Wickiewicz et al., 1984). The power output increased with movement velocity through to the fastest velocity of 5.0 rad·s^{-1}. This power-velocity relationship closely matched that found by Gregor et al. (1979) for an athletic group with greater than 50% fast-twitch fibers but did not demonstrate the plateau, or drop-off, which has been indicated at higher velocities (Perrine and Edgerton, 1978; Osternig et al., 1983).

The force-velocity relationship demonstrated by the IPF was similar to the IKE, although a continual rise was noted through to the 0.0 rad·s^{-1} measurement. Fugl-Meyer et al. (1979) described a comparable force-velocity relationship through a limited velocity range of 0.0 to 3.14 rad·s^{-1} for isokinetic plantar flexion. Wickiewicz et al. (1984) noted similar findings through to 4.61 rad·s^{-1} but with a substantial drop-off at the isometrically loaded condition. The discrepancy is attributable to the different isolation angles used at the hip and knee joints by the two studies for the plantar flexion assessment. The torque values in the present study are also similar to those reported by Falkel (1978) at velocities of 0.0 and

0.52 rad·s^{-1}. The IPF power outputs rose rapidly with increasing velocity to 2.0 rad·s^{-1}, peaked at 3.0 rad·s^{-1} and then dropped quickly displaying a parabolic relationship. No reports on the power-velocity relationship of the plantar flexors exist in the literature. It may be speculated that the observed drop in power development at the higher velocities was due, in part, to the inability of the plantar flexors to catch-up to the preset velocity of the dynamometer, particularly given the small range of the movement (about 0.9 rad).

The control group demonstrated no significant pre to post differences for IKE with the observed variations ranging from -2.6 to 3.3 percent for the seven velocities tested. This finding was consistent with the literature as the observed variance range was similar to (Johnson, 1980; Caiozzo et al., 1981; Coyle et al., 1981; Kanehisa and Miyashita, 1983) or smaller than (Moffroid and Whipple, 1970; Pipes and Wilmore, 1975; Smith and Melton, 1981; Vitti, 1984) those noted by other researchers.

Training of IKE at the low velocity of 1.0 rad·s^{-1} was found to increase the torque and power generated across all velocities from 0.0 to 5.0 rad·s^{-1} with the greatest enhancement occurring at the training velocity. Comparison with those studies which have evaluated a similar, singular, training velocity revealed that this finding was in close accord with the results of Kanehisa and Miyashita (1983) and similar to those of Caiozzo et al. (1981), Carr et al. (1981), Coyle et al. (1981) and Jenkins et al. (1984). All except Carr et al. (1981) and Kanehisa and Miyashita (1983) noted no enhancement at the highest test velocity of about 5.0 rad·s^{-1}, although interestingly, Jenkins et al. (1984) actually reported the largest percentage improvement for their low velocity training group at this velocity. The IKE training at 5.0 rad·s^{-1} resulted in significant increments only from 3.0 through 5.0 rad·s^{-1}, with the largest increase also being noted at the training velocity. This pattern compares favorably with data reported by Kanehisa and Miyashita (1983) and Caiozzo et al. (1981) for groups trained at 5.24 and 4.19 rad·s^{-1} respectively. However, improvements across a full range of velocities have been noted by Coyle et al. (1981) and Jenkins et al. (1984) after training at velocities of 5.24 and 4.19 rad·s^{-1} respectively. Other studies utilizing similar training velocities support the observed results but are limited in interpretive usefulness due to the use of variable training velocities within a group and the small number of velocities assessed (Smith and Melton, 1981; Vitti, 1984).

Formulation of a clear response pattern for velocity specific training is clouded further from the results of studies which have used an intermediate training velocity of 3.14 rad·s^{-1}. Reports have indicated improvements at and below this training velocity (Lesmes et al., 1978), only at that velocity (Petersen et al., 1984), as well as across all velocities (Kanehisa and Miyashita, 1983). The results of the present study, and those more recently cited, support the existence of a training specificity related to velocity. However, these recent results also provide substantial evidence to refute the initially stated, oft quoted and utilized, specificity of velocity training principle which was that training at a given velocity would result in improvements only at and below that specific velocity (Pipes and Wilmore, 1975; Counsilman, 1976; Sale and MacDougall, 1981). The argument gains further support from a re-evaluation of the initial reports which proposed this principle. The 'high' training velocities used by previous researchers were actually relatively slow in terms of both human movement and isokinetic dynamometer capabilities (Moffroid and Whipple, 1970; Pipes and Wilmore, 1975; Lesmes et al., 1978; Johnson, 1980). While interpretation of the available data supports a training specificity related to velocity, no generalizations regarding the effects produced by specific velocities appear warranted due to the discrepancies noted. The explanation for the divergence of results observed throughout the literature remains unclear but may be related to experimental design factors (subject characteristics, training regimen, testing protocols) or neuromuscular considerations (motor unit recruitment pattern, specificity of movement pattern, fiber type and size). The aforementioned neuromuscular considerations and their interrelationships will be discussed in order to help clarify the results produced by the present study.

Muscle fiber characteristics have been shown to have an influence upon the mechanics of muscle function. In general, muscles with a higher proportion of fast-twitch fibers have been shown to produce greater force at any given velocity (Thorstensson et al., 1976; Komi and Karlsson, 1978; Gregor et al., 1979). A similar effect has been noted in muscles which possess fibers of larger size (Thorstensson et al., 1976; Sale and MacDougall, 1981; Houston et al., 1983).

The utilization of these characteristics to produce useful contractile force is, however, dependent upon the rate and timing of muscle fiber recruitment within a given movement. The basic assumption for voluntary contractions has been that motor units are recruited according to their size, thus slow-twitch fibers will be recruited first (Henneman and Olson, 1965; Desmedt and Godaux, 1979; Komi et al., 1982). Evidence has been presented however, which indicates that fast-twitch fibers are preferentially recruited during high velocity, low tension contractions (Desmedt and Godaux, 1979; Grimby, 1982). Therefore, it would be possible within a group which was homogeneous with respect to fiber type to expect increments in force production at specific velocities based upon the above factor. Albeit, such an effect may not be detectable within a heterogeneously fiber typed group. While these recruitment patterns may be exhibited during isotonic contractions where the forces generated throughout the movement are variable, a similar pattern may not occur for isokinetic contractions. Although glycogen depletion studies support the differential fiber type recruitment pattern concept (Grimby, 1982), the data from EMG studies has shown that both fiber types contribute to force production at all velocities (Rosentwieg et al., 1975; Barnes, 1980; Sale and MacDougall, 1981). This recruitment pattern seems to occur due to the voluntary forces being maximal throughout the isokinetic movement. Such results may help resolve the apparent misconception that fast-twitch fibers are only involved in fast contractions and slow-twitch fibers with slow contractions (Counsilman, 1976; Sale and MacDougall, 1981).

Low velocity training has been shown to cause hypertrophy in all fiber types if the duration of the training program is long enough (Thorstensson et al., 1976; MacDougall et al., 1980; Hakkinen et al., 1981; Komi et al., 1982). High velocity training has failed to produce a similar contractile adaptation (Sale and MacDougall, 1981). One-legged training models have indicated that the untrained limb can produce increased force without demonstrating contractile alterations, such as hypertrophy, thus suggesting a neural adaptation (Lesmes, 1978; Costill et al., 1979; Krotkiewski et al., 1979; Houston et al., 1983). Also, resistance training studies have noted that neural factors appear to account for the early enhancements in force while later gains seem more related to hypertrophic alterations (Moritani and DeVries, 1979; Hakkinen et al., 1981; Komi et al., 1982; Houston et al., 1983). These results also lend support to the concept of neural adaptations producing the observed effect. While the explicit neural adaptation remains to be elucidated, a possible mechanism was suggested from the study of Milner-Brown et al. (1975) which described an enhancement in the synchronization of the electrical impulses generated by the motor units during weightlifting after completion of a resistance training program. Similar evidence has recently been reported by Roy et al. (1984). They noted significant alterations in the alphamotoneuron excitability of the quadriceps muscle with an increased motor unit recruitment after a ten week, low velocity (1.07 rad·s^{-1}) isokinetic training program. Additionally, it has been suggested that the selective hypertrophy of fast twitch fibers which occurs early in high resistance, low velocity training will reduce the time required to achieve a set force level in a dynamic contraction (Bosco and Komi, 1979a; Komi et al., 1982; Hakkinen and Komi, 1983). However, it is interesting to note that prolonged heavy resistance training, especially when using an eccentric mode, has been shown to reduce the force-time characteristics of muscle as well as skilled performance (Hakkinen et al., 1981; Komi et. al., 1982; Hakkinen and Komi, 1983).

These findings have led to the suggestion that to optimize the training effect for the enhancement of power or torque at high velocities, a training program should provide a combination of low velocity training for the contractile component and high velocity training for the neural factor (Sale and MacDougall, 1981). Further research will be required to conclusively determine if the hypertrophy of muscle fibers is a pre or co-requisite for neural adaptation within the neuromuscular system. This low/high velocity training contention is partially supported by the results of isokinetic training programs conducted through a range of velocities (Coyle et al., 1981; Smith and Melton, 1981; Vitti, 1984) as well as those where concurrent training using another mode at uncontrolled velocities occurred (Pipes and Wilmore, 1975; Kanehisa and Miyashita, 1983). While increments have been shown, they have not exceeded those produced through training at a specific velocity.

The existence of a specificity effect for movement patterns has been demonstrated on numerous occasions. In these instances, the force generation improvements observed on related non-specific tests (identical or similar pattern but different mode) have been less than those obtained from measurements of the specific test (ie. training task) (Gettman et al., 1980; Johnson, 1980; MacDougall et al., 1980). Support is also provided from the biomechanical analyses provided by Hay et al. (1983). They demonstrated that the joint torques exerted at the hip, knee and ankle varied substantially with alterations in the mode (ie. movement pattern) of resistance exercise used. This movement specificity effect was corroborated from the results of the present study which found the greatest improvements exhibited within the two groups corresponded to the training velocity used even though the general movement pattern was identical across all test velocities. The neuromuscular factor which varied to produce the results would have to be the motor unit recruitment pattern (synchronization and/or number of fibers) specific to the movement pattern at each velocity.

No significant pre to post differences were found for IPF in the control group. The range of variation noted, 5.7 to -10.3 percent, was larger than that observed for the IKE evaluation. For the ankle, training at the low velocity of 1.0 rad·s^{-1} resulted in significant improvements in torque at and just below this velocity while peak power was improved only at the training velocity. Training at the high velocity of 4.0 rad·s^{-1} resulted in significant enhancement of torque and power only at the training velocity. This latter conclusion is based upon a visual assessment of the results as the analysis of variance indicated the existence of significant differences at this velocity but the conservative post hoc test which was used failed to deliniate the location of the significance (Figure 5 and Table 57, Appendix E).

Comparison with the literature is not possible as no previous reports have evaluated this mode of training for the plantar flexors. These results are supportive of both the velocity-specific and specificity of movement pattern training concepts and are explainable by the neuromuscular concepts outlined under the discussion of the IKE training results. Unlike the IKE, significant carryover of the training effect did not occur although a similarity was noted in the response pattern across the velocities tested. This finding may be related to the duration of the training program (with the attendent neural and hypertrophic adaptation implications), the initial level of training, or the inherent neuromuscular characteristics of the plantar flexor muscle group (Fugl-Meyer et al., 1979; Sale and MacDougall, 1981; Clarkson et al., 1982).

ISOLATED VERTICAL BLOCK JUMP

The quantitative biomechanical analysis of standing vertical jumps has been sketchy at best. While several authors have provided bits of information, it has been of limited use in terms of applicability to training programs or skilled athletic performance due to the fragmentation of the analysis (Desipres, 1976; Coutts, 1978b), the different styles of jumps assessed (Martin and Stull, 1969; Coutts, 1978a; Adrian and Laughlin, 1983), sample size (Desipres 1976; Miller and East, 1976; Davies et al., 1982), or characteristics (age, sex, skill level) of the sample (Desipres, 1976; Coutts, 1978a; Adrian and Laughlin, 1983). In order to provide further information in this regard a cinematographic and force platform analysis was conducted. The kinetic, kinematic and temporal characteristics of an athletic male sample (n=30) without expertise in jumping who performed vertical volleyball block jumps from a stationary position are summarized in Table 9. As no differences were noted between the three groups on any [illegible] the measured variables at the start of the study, the

TABLE 9. Kinetic, kinematic and temporal characteristics of the vertical block jump.[1]

Characteristic		Mean	SEM	Range	
				Minimum	Maximum
Kinematic					
HTRCM	(cm)	48.40	.86	37.44	59.94
VELTO	$(m\cdot s^{-1})$	2.80	.04	2.46	3.23
MAH	$(rad\cdot s^{-1})$	1.44	.04	.94	1.85
MAVH	$(rad\cdot s^{-1})$	4.79	.09	4.00	5.90
VMXH	$(rad\cdot s^{-1})$	9.21	.17	7.19	10.68
MAK	(rad)	1.34	.03	.84	1.61
MAVK	$(rad\cdot s^{-1})$	6.02	.17	4.35	8.08
VMXK	$(rad\cdot s^{-1})$	11.86	.16	1[illegible].36	13.98
MAA	(rad)	1.43	.02	1.27	1.75
MAVA	$(rad\cdot s^{-1})$	4.40	.21	1.97	6.72
VMXA	$(rad\cdot s^{-1})$	9.24	.18	7.03	11.20
Kinetic					
GFOR	(N)	1194.91	41.84	790.34	1562.74
FNI	$(N\cdot s)$	7[illegible].20	3.83	13.49	119.63
PI	$(N\cdot s)$	220.60	5.81	157.90	275.87
SNI	$(N\cdot s)$	13.39	.69	7.94	20.97
TPI	$(N\cdot s)$	181.28	6.42	127.47	283.41
FMIN	(N)	309.37	31.55	67.01	808.95
FMAX	(N)	1790.37	47.45	1173.90	2306.98
Temporal					
TPIT	(s)	.80	.14	.51	1.06
FNIT	(s)	.36	.03	.21	.60
PIT	(s)	.41	.01	.27	.59
SNIT	(s)	.03	.00	.01	.04
TFMIN	(s)	.58	.02	.38	.91
TFMAX	(s)	.20	.01	.06	.31
MAVTH	(s)	.29	.01	.21	.36
MAVTK	(s)	.24	.01	.15	.36
MAVTA	(s)	.24	.01	.15	.42

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[1] Represents the pooled data (n=30) from the pre test session.

data was pooled for this description.

At 48.40 cm, the HTRCM was comparable to that reported for similar populations (Chui, 1950; Ball et al., 1964; Pipes and Wilmore, 1975; Bosco and Komi, 1979a; Bosco et al., 1983; Shields et al., 1985) and slightly lower than those values found for skilled athletes (Komi and Bosco, 1978; Clutch et al., 1983; Viitasalo and Aura, 1984) who performed the same basic style of jump. Similarly, the mean vertical velocity at take-off (2.80 m·s^{-1}) is within the range reported in the literature (2.48 to 3.03 m·s^{-1}) (Desipres, 1976; Lamb and Stothart, 1977; Komi and Bosco, 1978; Luhatanen and Komi, 1978; Davies et al., 1982). The minimum angles noted at the hip and knee were smaller (about 0.3 rad) than those of Eckert (1968b), whose skilled subjects used an unrestricted arm swing, and were therefore indicative of a more crouched position during the unweighting phase. The MAK of 1.34 rad was similar to the 1.42 rad measurement obtained by Adrian and Laughlin (1983) on skilled female subjects. However, it was much smaller than those minimum angles (1.57 and 1.83 rad) commonly recommended for skilled athletes (Scates, 1972; Bratton and Lefroy, 1980; Cardinal and Pelletier, 1983). These differences may be due to the use of unskilled subjects in the present study or be suggestive of the need for quantitative assessment to accurately determine this relationship, especially as it applies to optimizing performance.

Few studies have reported the angular velocities achieved by the joints of the lower limb during a vertical jump performance involving an unweighting phase. Cinematographically, Eckert (1968b) found mean angular velocities for the hip, knee and ankle of 5.8, 7.5 and 5.9 $rad \cdot s^{-1}$, respectively, while the present study determined values of 4.79, 6.02 and 4.40 $rad \cdot s^{-1}$. Desipres (1976) found angular velocities at the knee which ranged from 6.71 to 5.36 $rad \cdot s^{-1}$ and decreased with increasing age. Interestingly, Bosco et al. (1981) determined an angular velocity for the knee of 4.4 $rad \cdot s^{-1}$ using an electrogoniometer. It should be noted that this was the mean angular velocity observed through the 'prestretch phase' of the movement which is similar, but not identical to the phase measured in the present study.

The mean angular knee and ankle velocities of 6.02 and 4.40 $rad \cdot s^{-1}$, respectively, are slightly above the training velocities used for IKE (5.0 $rad \cdot s^{-1}$) and IPF (4.0 $rad \cdot s^{-1}$) by the high velocity group. The closeness of these velocities would suggest, according to the specificity of training principle, that an enhancement in performance could be expected from such training. This was not the case as no changes were noted in the VBJ performance after completion of the training program. This may, in part, be due to the VBJ performance being a ballistic movement composed of acceleration and deceleration phases while the training was isokinetic. When the maximal angular velocities noted for vertical jumps are considered, the comparability changes dramatically. The maximal angular velocity at the knee has been reported as 16.0, 22, 11.24 or 11.86 rad·s^{-1} by Eckert (1968b), Adrian and Laughlin (1983), Bosco and Komi (1979b) and the current study, respectively. The wide variation of the values may be attributable to the types of jumps assessed as well as the different methodologies used to calculate this variable. However, in all cases the recorded velocity easily exceeded the capabilities of isokinetic dynamometers commonly used for training (maximum of 5.24 rad·s^{-1}).

Very few reports exist which have defined and quantified the kinetic parameters of the standing vertical jump. The values obtained in the present study (Table 9) are in general agreement with those reported in the literature. The FNI at 76.20 N·s is comparable to the values reported by Miller and East (1976) for women, 69 N·s, and Bosco and Komi (1979a) for men, 118.8 N·s. The positive impulse (220.6 N·s) falls within the values determined by Davies et al. (1982), Miller and East (1976) and Bosco and Komi (1979a) which were 154, 232 and 335.5 N·s respectively.

At 1790.37 N the FMAX was greater than those observed by most researchers (1005 to 1162 N) on similar jumps performed by males of comparable mass (Coutts, 1978a; Luhtanen and Komi, 1978; Bosco and Komi, 1979a; Davies et al., 1982). Nevertheless, Bosco et al. (1981) have reported a value of 2484.64 N. Interestingly, both Miller and East (1976) and Adrian and Laughlin (1983) have determined relatively high values, 1500 and 1871.59 N respectively, for female subjects of substantially lower mass (61.0 and 63.6 kg). Similar relationships exist with respect to FMIN with forces reported at 29.5, 175 or 309.37 N by Miller and East (1976), Coutts (1978a) and the present study.

The discrepancies noted are most likely due to the variability of assessment methods and subject characteristics. Even within the present study, a large difference was noted between the maximal [illegible] reaction force as determined by two commonly utilized methodologies. The value determined by direct force platform measurement was 1790.37 N while a force of 1194.91 N was calculated cinematographically. Given the methodological procedures followed and that all other cinematographical and force platform data closely paralleled previous reports, no apparent reason was evident for this result. A significant measurement discrepancy has been shown previously between these two methodologies for the assessment of a vertical jump variable (Lamb and Stothart, 1977).

The temporal analysis of the performance (Table 9) was consistent with those identifiable portions of similar data provided in other studies (Eckert, 1968b; Miller and East, 1976; Coutts, 1978a). The quantification of the VBJ provided by the present study should assist with the design of future studies and be of value to coaches in their pursuit of more efficient training methods.

The three groups were matched on the criterion performance variable, HTRCM, at the commencement of the study. No significant differences were found on any of the biomechanical parameters measured at the pretest. As detailed previously, both experimental groups trained two of the muscle groups identified as major contributors to vertical jump performance utilizing an isolated mode similar to those commonly found in many training facilities. After completion of the training program, no significant difference was found for HTRCM, nor any of the other biomechanical variables measured, either within or between the three groups. The lone exception was the mean angular velocity of the hip which decreased in the HVG.

The present results contrast with the literature as virtually all previous studies have demonstrated improvements in the HTRCM after undertaking a resistance training program (see Table 10). No studies have assessed the effects of resistance training on the biomechanical charac-

TABLE 10. Comparative data on the effects of various resistance training programs on vertical jump performance.

Author	Year	Training		Vertical Jump^c (Δ cm)	Training Volume^d			Subjects			
		Type^a	Velocity^b (rad·s^{-1})		I	F	D	Age (yrs)	Sex	N per Group	Training Status^e
Chui^f	1950	Ist:Wb	na	7.2	1:8-12c	2-3	12	17-32	M	23	S;....
		Con:Ph	na	-0.1	Con	---	12	17-19	M	22	A;M
Berger	1963	Ist:Wb	na	2.3*	1:10c	3	7	17-22	M	29	A;E
		Ist:Sq	na	2.8*	1:6-8c	3	7	17-22	M	20	A;E
		Ism:Wb	na	0.8	1:6-8s	3	7	17-22	M	21	A;E
		Jmp	na	1.0*	1:10c	3	7	17-22	M	19	A;E
Ball	1964	Ism:Sq	na	1.2	1:10s	3	6	17-22	M	....	....
		Con	na	0.7	Con	---	6	17-22	M	....	....
Pipes and Wilmore	1975	Ist:Lp	na	1.02	3:8c	3	8	20-38	M	9	....
		ISK:Lp	0.42	2.79*	3:8c	3	8	20-38	M	9	....
		ISK:Lp	2.37	2.29*	3:15c	3	8	20-38	M	9	....
		Con	na	0.25	Con	---	8	20-38	M	9	....
VanOteghem	1975	ISK:Lp	≃ 0.8	....*	3:10c	3	8	17-22	F	16	TJ;E
		ISK:Lp	≃ 1.6	....*	3:10c	3	8	17-22	F	16	TJ;E
Thorstensson et al.	1976	Ist+Jmp:Sq	na	7.0*	3:6	3	8	24	M	22	A:E
Eisenman	1978	Ist+Jmp:Wb	na	2.0*	1:8-12c	4	6	>17	F	35	....,P
		Con	na	-0.5	Con	---	6	>17	F	10	....,P
Blattner and Noble	1979	ISK:Sq	....	4.92*	3:10c	3	8	>17	M	12	....;P
		Ply	0.86m	5.20*	3:10c	3	8	>17	M	11	....;P
		Con	na	0.72	Con	---	8	>17	M	15	....;P
Stevens^f	1980	Ist:Sq	na	3.45	5:5c	3	8	[illegible]	[illegible]	25	A;E
		ISK:Sq	....	6.91	4:10c	3	8	[illegible]	[illegible]	25	A;E
		Ist+ISK:Sq	....	4.39	5:5+4:10c	2+2	8	15-[illegible]	[illegible]	25	A;E

TABLE 10. Comparative data on the effects of various resistance training programs on vertical jump performance (continued).

Author	Year	Training		Vertical Jump^c (Δ cm)	Training Volume^d			Subjects			
		Type^a	Velocity^b (rad·s^{-1})		I	F	D	Age (yrs)	Sex	N per Group	Training Status^e
Wathen	1980	Ist:Sq	na	0.41*	5:5c	3	8	....	M	26	T;E
		ISK:Sq	....	0.29	5:20c	3	8	....	M	26	T;E
Smith and Melton^f	1981	Ist:Qi	na	0.84	3:10c	3	6	16-18	M	3	A+T;P
		ISK:Qi	.5+1+1.5	1.70	3:50%	3	6	16-18	M	3	A+T;P
		ISK:Qi	3+4+5	2.31	3:50%	3	6	16-18	M	3	A+T;P
		Con	na	-5.31	Con	---	6	16-18	M	3	A+T;P
Komi et al.	1982	Ist;Sq	na	-0.1	....	3	16	....	M	8	A;M
		Jmp	na	1.6	....	3	16	....	M	19	A;M
Clutch et al.	1983	Jmp+Ist:Sq	na	2.08*	4:10+3:6c	2	4	20.9	M	12	A;....
		Ply+Ist:Sq	0.3m	3.35*	4:10+3:6c	2	4	20.9	M	12	A;....
		Ply+Ist:Sq	.75+1.1m	2.97*	4:10+3:6c	2	4	20.9	M	12	A;....
		Ist:Sq	na	-0.11	3:6c	2	16	21.2	M	8	A;....
		Ply+Ist:Sq	.75+1.1m	3.73*	4:10+3:6c	2	16	21.2	M	8	A;....
		Ist:Sq	na	4.25*	3:6c	2	16	21.2	M	8	TJ;E
		Ply+Ist:Sq	.75+1.1m	3.21*	4:10+3.6c	2	16	21.2	M	8	TJ;E
Hakkinen and Komi	1983	Ist;Sq	na	2.4*	3:6c	3	16	26.4	M	14	T;M
		Con:Ph	na	0.0	Con	---	16	25.7	M	10	A;M
Viitasalo and Aura	1984	Jmp+Ist:Sq	na	4.0	Variable	3-5	45	22.6	M	8	T;E
Wiater et al.^{g}	1984	ISK:Wb	....	3.2* or 3.0*	....:20s	3	10	>17	F	13	....
		ISK:Wb	....	1.1 or 5.1*	....:20s	3	10	>17	M	10	....

TABLE 10. Comparative data on the effects of various resistance training programs on vertical jump performance (continued).

Author	Year	Training		Vertical Jump[c] (Δ cm)	Training Volume[d]			Subjects			
		Type[a]	Velocity[b] (rad·s^{-1})		I	F	D	Age (yrs)	Sex	N per Group	Training Status[e]
Shields et al.	1985	Ist:SLQ	na	4.6*	2:10-20c	3	8	13-18	M	17	A;....
		ISK:SLQ	.6 to 2.1	5.0*	2:....	3	8	13-18	M	19	A;....
		Con:Ph	na	0.7		3	8	13-18	M	17	A;....
Sexsmith (present study)	1985	ISK:Qi+Pf	1.0+1.0	-0.81	3:20s	4	5	21.8	M	10	T;M
		ISK:Qi+Pf	5.0+4.0	0.46	3:20s	4	5	23.0	M	10	T;M
		Con	na	0.50	Con	---	5	23.9	M	10	T;M

[a] ISK = isokinetic; Ist = isotonic, Ism = isometric; Jmp = vertical jumping; Ply = plyometric; Con = control; Wb = whole body; Sq = squats; Lp = leg press; Qi = isolated knee extensors; SLQ = Sq + Lp + Qi; Pf = isolated plantar flexors; Ph = physical education class.

[b] na = not applicable; m = height used in meters for depth jumps; .... indicates no value reported.

[c] Values reported are post minus pre training program measurements; An * indicates that the reported difference was significant.

[d] I indicates intensity as a number of sets and a number of contractions per set (c) or a number of sets and a duration in seconds per set (s) or as a percentage of the initial peak torque which demarcated the cessation point of a continuous bout (%); F indicates frequency as days per week; D indicates duration in weeks.

[e] S = sedentary; A = active recreationally; T = trained athlete; TJ = trained athletes in a jumping sport; M = maintenance of pre training program activity level (S, A, T or TJ) throughout the study; P = prohibition of all other forms of training for duration of study; E = extra training activities concurrent with training for the study.

[f] No statistical analysis was done on the vertical jump measurements.

[g] Values reported were on the same vertical jumps as measured by jump and reach or cinematographic techniques.

teristics of the vertical block jump. The results are also interesting considering that significant enhancement of the force and power capabilities of the involved muscle groups were found for both isokinetic training groups. The explanation for these findings may lie in the neuromuscular physiology realm.

Except for the report of Komi et al. (1982), studies which have utilized an isotonic or isokinetic training mode with a movement pattern similar to that of a vertical jump (squats, plyometrics, jumping) have consistently shown increments in performance (Berger, 1963; Thorstensson et al., 1976; Eisenman, 1978; Blattner and Noble, 1979; Clutch et al., 1983; Hakkinen and Komi, 1983; Wiater et al., 1984). It is difficult to make inferences from the study of Smith and Melton (1981) due to design factors. However, it is the sole report which trained a muscle group (the knee extensors) in an isolated manner. Their sample of athletes' and non-athletes demonstrated an increase in the vertical jump after the isokinetic training, although an n of three per group negated statistical treatment of the data. The present study also trained the knee extensors isokinetically in an isolated manner but found no enhancement of vertical jump performance. While the methodology ensured that the subjects underwent a minimum of 1.6 radians of extension in the isokinetic training, the kinematic analysis of the VBJ performance revealed that the average extension movement was through 1.8 radians. It is not known, however, whether the results documented above were due to the resistance training applied or the pattern of movement or a combination of those two factors.

Cumulatively, these results suggest that performing the basic movement pattern of the skill may be an important factor for the enhancement of that skilled performance through a resistance training program. This suggestion would imply that a neural component related to the recruitment of the motor units involved is, at least in part, responsible for the increases noted from such training programs. The contention that performing the skilled movement pattern affects the training effect is compatable with the variable performance results noted where concurrent physical activity was either superimposed over the training program or not controlled (Pipes and Wilmore, 1975; VanOteghen, 1975; Stevens, 1980; Wathen, 1980; Smith and Melton, 1981; Clutch et al., 1983; Viitasalo and Aura, 1984). Further evidence has been provided by the elbow extension studies of MacDougall et al. (1979, 1980). They demonstrated that the addition of an isokinetic dynamometer practice component to a previously used weight program resulted in no further enhancement of arm girth or weight lifting strength, but it did increase significantly the isokinetically generated torque thus implying a specificity of movement pattern training effect. Viitasalo and Aura (1984) have also shown that over a ten month period the time course of an increase in the isometric strength of the leg extensors does not match the improvements seen for a vertical jump performance in skilled athletes. The concept is also supported by the neuromuscular relationships pertaining to the specificity of training effect for velocity and movement patterns as outlined previously in the isokinetic training section.

The concept of requiring practice of the movement pattern of a skill in order to achieve performance increments would explain the results found in the present study. While the extensor muscle groups demonstrated as being major contributors to the VBJ were trained isokinetically at a velocity approaching that observed in the skilled VBJ performance, care was taken in the design to ensure that: 1) the isokinetic training of the muscle groups was in an isolated movement pattern, 2) the subjects chosen were not familiar with the VBJ movement pattern, and 3) the subjects did not practice the VBJ movement during the duration of the training program. Given these conditions, the results obtained followed closely what would have been predicted from the specificity of velocity and specificity of movement pattern training concepts.

RELATIONSHIPS BETWEEN SELECTED VARIABLES

The interrelationships amongst force, velocity and time characteristics of the criterion muscular performances were determined. Both body mass and lean body mass have been previously shown to be positively related to the force and power production of the knee extensor and plantar flexor musculature (Thorstensson, 1977; Falkel, 1978; Beam et al., 1982). The lack of any significant relationship between these variables in this study was expected since the force and power outputs of the knee extensors and plantar flexors were expressed relative to body mass. Consistent with the literature, neither body mass or lean body mass were found to be related to HTRCM, but MASS did demonstrate a significant positive relationship to FMAX and TPI (Costill et al., 1968; Eisenman, 1978; Genuario and Dolgener, 1980).

The force and power outputs of the knee extensors and plantar flexors demonstrated significant correlations both within and between themselves. The strength of these relationships was fairly consistent across the range of velocities tested. Additionally, the closer the velocities were to each other the greater the strength of the relationship. These findings parallel those of Bosco et al. (1983).

As demonstrated by previous research (Perrine et al., 1978; Bosco and Komi, 1979a) significant correlations existed amongst HTRCM, VELTO and PI although the strength of the relationships were lower than expected from a theoretical perspective (Hay, 1978). In part, the reduced correlations would be expected as the part played by body mass was not considered in these relationships. Also, some error would be attributable to the sensitivity of the measurement instrumentation (Lamb and Stothart, 1977). The high correlation between VELTO and HTRCM (r=0.8838) indicates the accuracy of the film reduction methodology.

Contrary to the literature (Perrine et al., 1978; Bosco and Komi, 1979a), no significant relationships were found between the HTRCM and several of the kinetic variables which characterized the different phases of the VBJ. This finding could be due to the efficiency of movement, as those reports demonstrating significance used subjects familiar with the VBJ movement pattern while the current study used individuals who were unskilled in this performance. It is known that the efficiency of a vertical jump performance is affected by such factors as the utilization of stored elastic energy (Asmussen and Bonde-Petersen, 1974; Komi and Bosco, 1978; Bosco et al., 1982b), the reflex potentiation of muscle activation (Bosco and Komi, 1979b; Bosco et al., 1981; Bosco et al., 1982a), muscle fiber characteristics (Bosco and Komi, 1979a; Hakkinen et al., 1981; Viitasalo et al., 1981), and the synchronization of the segmental contribution (Hubley and Wells, 1983; Hudson and Owen, 1983).

While the minimum angles achieved during the performance of a vertical block jump have been suggested as being critical for the successful execution of this skill (Bratton and Lefroy, 1980; Cardinal and Pelletier, 1983), no relationships were found between the minimum angles or angular velocities of the knee and ankle joints with HTRCM. However, both HTRCM and VELTO demonstrated a negative relationship with the minimum angle at the hip. This finding is interesting as it may reflect the importance of the correct sequencing of the inertial contribution of the body segments to a successful VBJ performance (Luthtanen and Komi, 1978; Hubley and Wells, 1983; Hudson and Owen, 1983).

The literature has indicated no conclusive relationship between the isometric strength of the leg extensors and vertical jump performance. The correlations reported have been negative (Costill et al., 1968), positive (Berger and Henderson, 1966; McClements, 1966; Eisenman, 1978), or non-significant (Viitasalo et al., 1981). Viitasalo and Aura (1984) have shown high correlations between HTRCM and isometric force production of the knee extensors (r=0.91) and plantar flexors (r=0.92) in elite high jumpers. The present study demonstrated no significant correlations bewteen HTRCM and isometric knee extension ($r=-0.01$) or plantar flexion ($r=0.27$). These differences may be due to the variation in methodology (angles of measurement and stabilization) as well as the skill level of the subjects. A positive relationship between HTRCM and isokinetic torque production of the leg extensors has been reported by Perrine et al. (1978) at an undefined velocity. Genuario and Dolgener (1980) found significant relationships between HTRCM and both isokinetic knee extension and plantar flexion at a velocity of 3.14 $rad \cdot s^{-1}$. However, measurements conducted at 0.52 $rad \cdot s^{-1}$ were found to be non-significant. A similar significant positive relationship has been reported by Bosco et al. (1983), but only at isokinetic velocities from 2.0 to 5.2 $rad \cdot s^{-1}$. The present study demonstrated a positive relationship between HTRCM and IKE only at the 3.0 and 5.0 $rad \cdot s^{-1}$ velocities. A similar relationship was found for IPF solely at 1.0 $rad \cdot s^{-1}$. While the force production of the leg and knee extensors has been shown to be related to HTRCM, it has been noted that the increases in force production were not related to increments in VBJ performance (McClements, 1966; Viitasalo and Aura, 1984). This independence of the training effect from the relationships noted between muscular force production and the performance of a skilled movement was found in the present study. These findings corroborate the concept of a movement pattern specificity effect with respect to resistance training.

SUMMARY AND CONCLUSIONS

The purposes for which this study was designed were achieved as:

1. two single joint muscular contractions (knee extension and plantar flexion) and one skilled muscular impulse performance (a controlled, stationary vertical block jump) were isolated and characterized quantitatively;
2. the effects of two specific velocities of isokinetic dynamometer training for the isolated knee extensor and plantar flexor muscle groups upon these performances were quantitatively evaluated; and
3. the relationships between selected physiological and biomechanical characteristics of these performances were assessed.

The results were discussed in light of the related literature with an emphasis placed upon interpretation from a neuromuscular perspective to clarify, where possible, the underlying mechanisms.

Accomplishment of the initial purpose provided the addition of previously unavailable quantified descriptions of the three performances to the literature. Low velocity isokinetic training of the knee extensors was found to significantly elevate both the force-velocity and power-velocity curves across all velocities, while enhancements from high velocity training were restricted to the high velocity portion of these curves. A similar effect was noted from the isokinetic plantar flexion training, however, the enhancements were limited to the velocity at which the training occurred. Although significant increases in torque and power production were achieved from the two isokinetic training programs; no alterations occurred in the performance of the VBJ skilled performance. These results support the concepts of specificity of velocity as well as a specificity of movement pattern training effect. The underlying physiological mechanisms responsible appear to be neuromuscular in origin, probably centering around the pattern and synchronization of motor unit recruitment within these movements. Although the performances assessed were closely related in terms of the muscle groups being utilized, the lack of relationship between the characteristic parameters of the two modes of performance indicates their independence and supports the importance which neural factors appear to have in resistance training and skilled performance.

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APPENDIX A

REVIEW OF LITERATURE

Understanding the interrelationships amongst neuromuscular physiology, resistance training and skilled performance in athletic events and how they interact to improve performance is a complex conceptual task. The purpose of this literature review is to provide a unified perspective upon a selected area of this topic. The review provides a progressive examination of the relationships and interactions between the three aforementioned areas with specific emphasis upon muscle characteristics (structural and functional), isokinetics (concept, measurement and training), training velocity and standing vertical jump performance. During this synthesis, care has been taken to note confounding factors in the reported research which have masked a clear understanding of the area for the researcher, coach and athlete.

The term isokinetic refers to a muscular contraction which is at or near maximal in force generation throughout the range of joint movement with the angular velocity of the limb being constant except near the extremes of the range of motion where acceleration-deceleration phases occur (Thistle et al., 1967; Hinson et al., 1979). The design, validity and capabilities of a dynamometer employing this principle, the Cybex II isokinetic dynamometer (Lumex Inc.), has been discussed by several researchers (Hislop and Perrine, 1967; Moffroid et al., 1969; Rothstein et al., 1983). From the perspective of studying the force-velocity relationships of human muscle, the unique characteristic offered by an isokinetic dynamometer is that of controlling the movement velocity while allowing the force to vary throughout a range of motion. Therefore, velocity rather than force may be considered as the independent variable.

Dynamic evaluations have shown the measurement characteristics of the Cybex II system to be essentially linear throughout its angular and velocity ranges with slight increases in variability occurring at higher velocities or smaller torques (Moffroid et al., 1969; Murray et al., 1982). Repeated calibrations have indicated that the system remains accurate within approximately ±3% (±5 N·m) of its measurement range (Thorstensson et al., 1976; Coyle et al., 1981). Commonly reported test-retest reliability values for the Cybex II isokinetic dynamometer, as determined under various load and velocity conditions, have ranged from r=0.930 to 0.998 (Moffroid et al., 1969; Thorstensson et al., 1976; Johnson and Siegel, 1978; Sherman et al., 1981). Several studies have also been conducted investigating subject reliability under a variety of velocity, sequencing, time and fatigue conditions for both consecutive and randomized trials. The variation within subjects has been consistently reported as being between 3 and 10 percent with the differences noted being non-significant when considered as grouped data (Thorstensson et al., 1976; Lesmes et al., 1978; Molnar et al., 1979; Sherman et al., 1981; Mawdsley and Knapik, 1982; Fleck et al., 1984). In general these results have indicated that for inexperienced subjects peak torque data may be measured with confidence on an isokinetic dynamometer across all velocities from a small number of trials on a repeated basis over time.

Recently, questions have arisen regarding potential inherent sources of error within the Cybex II isokinetic dynamometer system and what potential effects they would have upon the interpretation of the generated data. Upon initiation of movement, the accelerating limb must in essence catch-up to the preset velocity of the dynamometer. When the preset velocity is attained a large initial transient torque reading, with subsequent compensatory oscillations, is generated and is especially noticeable at higher velocities (Perrine and Edgerton, 1978; Murray et al., 1982). It has been determined that this initial reading is an electromechanical overshoot phenomenon within the dynamometer caused by the inertial force of the suddenly decelerated limb and is not an accurate reflection of tension development from the assessed muscle group (Sapega et al., 1982). It may therefore be concluded that this portion of the torque curve should be removed or smoothed for analysis purposes. The Cybex II system does contain an electronic damping circuit to remove or supress erroneous torque input such as overshoot (Lumex Inc., 1980). It has been found however, that use of the damping circuit, especially beyond a setting of two, results in significant suppression of the amplitude of the entire torque curve as well as creating a time delay in the torque trace with both effects being magnified at higher angular velocities (Sapega et al., 1982; Sinacore et al., 1983). This last factor may be a consideration when testing at higher velocities as it has been shown for the knee extensors that the angle at which peak torque occurs increases with velocity (Perrine and Edgerton, 1978; Gregor et al., 1979). Techniques which may be utilized to avoid these potential errors include sampling data past the point where the initial oscillations occur, maximizing the artifact-free section of the torque curve by increasing the range of limb movement, and ensuring that all recording-damping factors are identical when conducting repeated tests over time.

When the Cybex II system is used with the lever arm moving in the vertical plane the muscular contractions of the limb being tested are either opposed or assisted by gravity. Gravitational errors occur due to both the weight of the lever arm and the limb. The magnitude of the recorded torques are erroneously low for contractions against gravity while those with gravity are high, with the error occurring across all velocities and being up to 43 and 510%, respectively, in terms of mechanical work (Winter et al., 1981; Roush, 1984). The errors are greatest near the end of extension movements (i.e. against gravity) and at the initiation of flexion around joints such as the knee and may result in a misinterpretation of muscle function. Winter et al. (1981) reported resolution of this problem through a technical (accelerometer) approach whereas Nelson and Duncan (1983) applied a mathematical formula. Some researchers have chosen to avoid potential gravitational errors by altering a commonly used testing protocol to allow evaluation of the movements in the horizontal plane (Tihanyi et al., 1982). While the gravitational influence often produces incorrect absolute torque data from the Cybex II system, this type of error would not affect the comparability of unattenuated data from studies utilizing a test-retest design.

One of the advantages offered by the isokinetic dynamometer is that of evaluating the functional performance of an isolated muscle group. To ensure adequate isolation of the muscle group, appropriate positioning and stabilization of the body must occur. The protocol recommended by the Cybex II system manufacturer (Lumex Inc., 1980) has indicated that only the hips and tested limb be stabilized for assessment of knee extension or plantar flexion. Richard and Currier (1977) found that stabilization of the back significantly enhanced the peak torques measured in knee extension. Stabilization of the nontested limb did not effect the torque generation of the knee extensors at velocities of 3.14 $rad \cdot s^{-1}$ or less (Patteson et al., 1984). Fugl-Meyer et al. (1979) determined that peak plantar flexion torques measured at velocities ranging from 0.0 through 3.14 $rad \cdot s^{-1}$ were significantly greater when the knee joint was positioned at 0.0 versus 1.57 radians. They attributed this phenomenon to the more optimal length-tension relationships for both the gastrocnemius and soleus muscles.

The application of the isokinetic exercise concept, and the isokinetic dynamometer, has been most extensive in the areas of musculo-skeletal injury evaluation and rehabilitation (Moffroid et al., 1969; Goslin and Charteris, 1979; Sherman et al., 1981). Recently, applications have extended to elite athlete profiling (Thorstensson et al., 1977; Gregor et al., 1979; Smith et al., 1982), use as a training methodology (Pipes and Wilmore, 1975; Lesmes et al., 1978; Jenkins et al., 1984), and the in vivo evaluation of the force-velocity and power-velocity relationships of skeletal muscle (Perrine and Edgerton, 1978; Caiozzo et al., 1981; Wickiewicz et al., 1984).

The theoretical and experimental basis of the force-velocity relationships of skeletal muscle has been documented by Hill (1970). In-vitro experiments utilizing isolated amphibian and mammalian muscle preparations have shown that an inverse exponential relationship exists between contractile force and contraction velocity with the force of contraction being maximal when the velocity is zero while the contraction velocity is maximal when the resistive force is zero. A similar relationship has been suggested for human skeletal muscle loaded isometrically and isotonically in-vivo (Wilkie, 1950; Tihanyi et al., 1982). Recent in-vivo investigations utilizing isokinetic dynamometers have revealed that human skeletal muscle appears to follow this relationship quite closely (Komi, 1973; Jorgensen, 1976; Thorstensson et al., 1976), except when nearing the force and velocity extremes where an asymptotic effect may appear possibly due to protective neuromuscular inhibition (Perrine and Edgerton, 1978; Caiozzo et al., 1981).

Isokinetic dynamometer evaluation of the force-velocity relationship of the knee extensors have shown that as the velocity of movement increases the angle at which peak torque occurs, approximately 1.15 radians, decreases slightly (Thorstensson et al., 1976; Grimby, 1982). The reasons for this shift include the greater time for and range through which acceleration occurs, the changing angle of pull, and the length-tension relationship of muscle. Two methodologies have been used to assess force- and power-velocity relationships. The most common has been to measure peak torque as generated within the tested range of motion (Thorstensson et al., 1976; Lesmes et al., 1978; Coyle et al., 1979). The joint position dependent method has involved measuring the torque generated at a constant angle, usually 0.52 radians (Perrine and Edgerton, 1978; Gregor et al., 1979; Caiozzo et al., 1981). These authors have suggested that this method possesses more validity for making comparisons to Hill's classic force velocity relationship by ensuring completion of the acceleration phase and quietening of the initial measurement oscillations. Portions of their reasoning have been questioned by the results of Thorstensson et al. (1976) who demonstrated that the time lag due to acceleration does not affect peak torque measurements; Coyle et al. (1979) who determined that the peak torque method was a more reliable measure; and Yates and Kamon (1983) who found that both methods produced force-velocity curves which were basically identical, varying only in magnitude, for a heterogeneous population. Yates and Kamon (1983) did note, however, that only the constant angle approach elucidated a divergence in the force-velocity curves between homogeneous groupings based upon muscle fiber composition. From the literature it would appear that both methodologies are valid and reliable, and any choice for use should be based upon the purpose of the study.

The force-velocity-power capabilities of human skeletal muscle are very important whenever movements requiring a range and coordination of force and velocity are required. Many sports activities require that 'maximal' contractile forces be combined with 'maximal' contraction velocity in order for the generated forces to be optimally transformed to mechanical power for successful performance (Thorstensson et al., 1976; Perrine et al., 1978; Bosco and Komi, 1979a). The determination of the power-velocity relationship of human muscle has been studied isokinetically, usually through the determination of instantaneous power from the product of peak force and velocity (Perrine and Edgerton, 1978; Gregor et al., 1979; Osternig et al., 1983). The instantaneous power output of the isolated knee extensors has been shown to increase in a curvilinear manner peaking at 4 to 5 rad$\cdot$s^{-1} (Perrine and Edgerton, 1978; Gregor et al., 1979). A recent report by Osternig et al.

(1983) has supported this basic relationship, but a further linear increase up to 7 rad·s^{-1} was observed after the initial plateau. They used a constant angle measurement technique and attributed the further power increases to the increased velocity as the torques produced were found to remain fairly constant. While evidence from isokinetic studies seems to contradict some of the classic isometric and isotonic findings, the generalization that the peak mechanical power output will be produced when both the force and velocity of a contracting muscle are between approximately 30% to 60% of their maximum still seems acceptable (Perrine and Edgerton, 1978; Davies et al., 1982; Osternig et al., 1983).

The importance of this concept has been corroborated by evidence obtained from cross-sectional studies on elite athletes involved in sports where skilled power or impulse performance was critical to success (Thorstensson et al., 1977; Campbell, 1979; Gregor et al., 1979). In general the studies have demonstrated elevated force-velocity and power-velocity relationships for such athletes when compared with either sedentary or endurance trained individuals. Elevated force-velocity and power-velocity relationships have also been positively correlated to the proportional fast-twitch fiber population in heterogeneous groups (Thorstensson et al., 1976, 1977; Coyle et al., 1979; Gregor et al., 1979; Ivy et al., 1981). As well, Larsson et al. (1979) have noted correlations for both static and dynamic strength with fast-twitch fiber area but, interestingly, not with fast-twitch fiber population. They also demonstrated that knee extension velocity was correlated with the fast-twitch fiber population. The numerous reports which have demonstrated positive relationships between muscle fiber characteristics and force-velocity relationships has often led to the inference of a causal relationship. However, this generalization is not warranted from such data. Several confounding factors exist including the populations tested (athletic versus non-athletic), the known limitations of muscle fiber-typing, other muscle characteristics (fiber length, motor unit recruitment), and the measurement velocities utilized (Fugl-Meyer et al., 1979; Wickiewicz et al., 1984). With respect to measurement velocity it is interesting to note that the commonly used Cybex II system operates at velocities up to 5.24 rad·s^{-1} while peak instantaneous velocities for knee extension have been reported at nearly 11.0 rad·s^{-1} on a modified dynamometer (Larsson et al., 1979) and appear to reach the 12 to 22 rad·s^{-1} range in skilled athletic performances (Eckert, 1968b; Adrian and Laughlin, 1983).

Progressive overload resistance training has been shown to alter the force-velocity and power-velocity relationships of human skeletal muscle. Support of a specificity of training concept has been suggested from studies which demonstrated that traditional high resistance, low velocity/repetition training enhanced the force-velocity curve only at low velocities (Lesmes et al., 1978; Anderson and Kearney, 1982). However, only minimal effects were elicited upon either the power-velocity curve or the maximal mechanical power output from such training programs. The importance of the velocity component of the force-velocity relationship, in terms of training to optimize muscular performance capacities, has been expressed by several researchers (Henry and Whitley, 1960; Moffroid and Whipple, 1970; Pipes and Wilmore, 1975). Few quantified studies exist which have focused upon the velocity component of a resistance training program. Clarke and Henry (1961) found that isotonic resistance training of the shoulder and arm musculature increased both arm strength and the speed of arm movement. Hellenbrandt and Houtz (1958) found that the power-velocity curve for arm supination was significantly increased by progressively overloading either the applied resistance or rate of limb movement within the isotonic training program. A combined isometric-isotonic training program for the arm musculature was found by Smith and Whitley (1965) to produce a significant increase in strength throughout the range of motion. However, the program increased the speed of movement only near the end of the range of motion and actually resulted in a decrease at the mid-range.

Further research on the velocity component was not evidenced in the literature until the advent of isokinetic dynamometers which allowed for easier quantification of the force-velocity relationships in isolated muscle groups. Initial research efforts were aimed at gathering evidence to support or refute claims of a superior training effect from isokinetic exercise due to its velocity specificity. This was attempted through comparing the effectiveness of isokinetic training methods to traditional isometric and isotonic training programs. Studies measuring the force, work and power capacities of lower body muscle groups have indicated a superiority when compared to either isometric (Thistle et al., 1967; Moffroid et al., 1969) or constant resistance isotonic (Thistle et al., 1967; Moffroid et al., 1969; Pipes and Wilmore, 1975) training programs. In contrast, Stevens (1980) demonstrated greater improvement from isotonic training, while DeLateur et al. (1972) showed no significant difference between the results obtained from a constant resistance isotonic versus isokinetic dynamometer training program. Smith and Melton (1981) and Shields et al. (1985) found no significant differences in the strength and endurance gains achieved from training on either isokinetic or variable resistance isotonic training programs. Several studies have noted a specificity of training effect in that while no clear superiority was evidenced between training modes, significantly greater increments were seen when the evaluation was conducted utilizing the training apparatus (Gettman et al., 1980; Johnson, 1980; Smith and Melton, 1981; Shields et al., 1985). The differences noted may also be attributable to experimental design, the volume of training or the proportional muscle fiber composition of the subjects.

The first isokinetic dynamometer research efforts directed towards evaluating the specificity effect of velocity in training indicated that isokinetic training at relatively high velocities elevated that portion of the force-velocity curve at or below the training velocity. Similar effects were found for maximal power output and the power-velocity curve. For example, the effects of isokinetic dynamometer training velocity were explored by Moffroid and Whipple (1970) at 0.63 and 1.88 rad·s^{-1}, Pipes and Wilmore (1975) at 0.42 and 2.37 rad·s^{-1}, and Lesmes et al. (1978) at 3.14 rad·s^{-1}. In all cases, the significant increments in force generation were noted only at or below the velocity at which the training occurred. They concurred that these findings supported the concept of a training specificity component for muscular contraction speed attributable to either muscle fiber composition or motor unit recruitment.

More recent research has produced divergent results. In contrast to previous reports, Caiozzo et al. (1981) found that high velocity training (4.19 rad·s^{-1}) resulted in significant improvements only at velocities greater than 2.5 rad·s^{-1}, while low velocity training (1.68 rad·s^{-1}) produced gains at all velocities up to, but not including, 5.03 rad·s^{-1}. Comparable results were found by Smith and Melton (1981). They reported gains at both a low and high velocity for a group trained at a variety of low speeds but gains only at a high velocity for a high speed training group. Jenkins et al. (1984) found that a group trained at 1.04 rad·s^{-1} only showed peak torque increases between 1.04 and 4.19 rad·s^{-1} inclusive, while a group trained at 4.19 rad·s^{-1} demonstrated increments across all velocities tested. Utilizing a protocol in which the total work performed during training was equated for each group, Coyle et al. (1981) observed that slow velocity training (1.0 rad·s^{-1}) produced gains only up to 3.14 rad·s^{-1}. The peak torque output was increased across all velocities (0.0 to 5.24 rad·s^{-1}) for subjects who trained at the 5.24 rad·s^{-1} velocity. Interestingly, a similar effect across all velocities was demonstrated by a group trained on a mixed velocity protocol, one-half of total work at each of 1.[illegible] and 5.24 rad·s^{-1}. Kanehisa and Miyashita (1983) trained groups of subjects at velocities of 1.05, 3.14 or 5.24 rad·s^{-1}. After training, both the low and intermediate velocity groups demonstrated increments in power output at all velocities tested (1.05 through 5.24 rad·s^{-1}). Enhanced power output was observed only at the highest two test velocities in the high velocity group. Carr et al. (1981) conducted a study in which subjects trained one leg at a slow velocity (0.84 rad·s^{-1}) and the other leg at a higher velocity (3.35 rad·s^{-1}), with training equated in terms of total work. Both legs showed significant increases in strength and reduction in time to peak torque at all velocities tested. They concluded that the gains noted were related to the total work performed rather than a velocity specificity in training. Adding further confusion are the studies of Petersen et al. (1984) and Vitti (1984). Petersen et al. (1984) reported an increase in peak torque at 3.14 rad·s^{-1} for a group trained at that velocity, but noted a decrease at a slower (1.04 rad·s^{-1}) test velocity. Vitti (1984) found no differences between groups trained at a combination of low velocities (1.0 to 2.5 rad·s^{-1}), high velocities (3.5 to 5.0 rad·s^{-1}) or all velocities (1.0 to 5.0 rad·s^{-1}). In all cases an enhancement of peak torque occurred at a high test velocity (4.0 rad·s^{-1}) but no change was observed at a low velocity

(1.0 rad·s^{-1}). The results of these studies would seem to indicate that a specificity factor does exist with respect to the velocity of training. This interpretation has led many researchers to recommend that athletes undertake resistance training programs at velocities approximating or exceeding those experienced in their sport (Pipes and Wilmore, 1975; Sale and MacDougall, 1981; Grimby, 1982). However, creating any generalizations regarding the specificity of velocity for application to training programs must be done with care due to the great variations in methodology, control and quantification of both the training and evaluative techniques exhibited by these studies. Also, the theoretical considerations provided through our understanding of neuromuscular architecture and functioning must be addressed.

In order to design resistance training programs for the purpose of optimizing skilled athletic performance it is necessary to understand what relationships exist between skilled performance and both skeletal muscle characteristics and resistance training regimens.

Several studies have demonstrated a positive correlation between fast-twitch fiber composition and both strength and high tension and/or speed performances in athletic groups as well as for heterogeneous populations (Thorstensson et al., 1977; Gregor et al., 1979; Clarkson et al., 1980; Ivy et al., 1981). Conversly, other authors utilizing similar populations and measurement techniques have found no relationship (Thorstensson, 1977; Komi and Karlsson, 1978; Campbell et al., 1979). The lack of consensus would indicate that generalizations regarding performance solely from fiber composition data are unwarranted.

Few studies have attempted to delineate whether relationships exist between vertical jumping ability and neuromuscular characteristics. Campbell et al. (1979) found no correlation between fast-twitch fiber composition and vertical jump performance in a group of 24 young females. Six weeks of anaerobic training showed no influence upon this observation. In a study involving 34 male physical education students, significant positive correlations were found between the proportional fast twitch fiber composition of the vastus lateralis and performance in standing vertical jumps with (r=0.48) and without (r=0.37) an unweighting phase (Komi and Bosco, 1977; Bosco and Komi, 1979a). Relationships were also shown between the percentage of fast twitch fibers and certain force-time characteristics including the average force (r=0.52), net impulse (r=0.45) and average mechanical power (r=0.52) for the vertical jump without unweighting. However, only net impulse (r=0.51) demonstrated this relationship in the jump with an unweighting phase. The explanation proffered for these results was that the intrinsic mechanical properties of fast and slow twitch fibers coupled with their variable ability to store and utilize elastic energy is a determining factor in multijoint muscular performances. In a further study, Bosco and Komi (1979a) determined that subjects with a higher percentage of fast twitch muscle fibers had a higher rise of center of mass in jumps both with and without an unweighting phase. The authors suggested the results supported the hypothesis that individuals possessing a higher percentage of fast twitch fibers are able to recruit their motor units in a more explosive manner.

The myoelectric activity of five lower limb muscles was studied by Viitasalo and Bosco (1982) during different vertical jumping conditions. The six male subjects were divided into two groups based upon the percentage distribution of muscle fiber types ([illegible]% or <50% slow twitch fibers) in the vastus lateralis. No differences were found between the two groups for the individual or integrated myoelectric activities within the five muscles in the various jumping conditions. The two groups displayed similar results with respect to the height jumped in the various conditions. However, the >50% slow twitch fibers group demonstrated a higher relative rise of the center of mass in jumping conditions which involved either an unweighting phase or a drop condition as compared to a static jump.

These results were interpreted as being indicative of a better utilization of elastic energy by subjects having a greater percentage of slow twitch muscle fibers.

Numerous studies have been undertaken to examine the relationship between characteristics of the skeletal musculature and performance in standing jumps. The strength profiles of various muscle groups have been examined with mixed results. Eckert (1964) found no correlation between isometric (whole-body) strength and broad jump performance in a group of 8 to 12 year old boys. In contrast, McClements (1966) demonstrated a significant relationship between the isometric strength of various muscle groups and vertical jump performance in adults. The same relationship was found by Berger and Henderson (1966) for both isometric and isotonic strength measurements of the knee and hip extensors. Eisenman (1978), however, noted a significant relationship between the isometric strength of only one group, the knee extensors, and the vertical jump. Tihanyi (1984) corroborated these findings with observation of a significant correlation between maximal dynamic strength in the knee extensors and the production of maximal power. While Viitasalo et al. (1981) found no correlation between vertical height jumped and peak isometric force of the leg extensors, they did notice a significant negative correlation with the time of isometric force production.

This finding was interesting as their subjects were a group of elite high jumpers and weight lifters.

Isokinetically, significant correlations have been found between peak torque of the knee extensors, knee flexors and plantar flexors at 3.14 $rad \cdot s^{-1}$ and vertical jump performance (Genuario and Dolgener, 1980). Bosco et al. (1983) also found a strong correlation between maximal isokinetic torque in the knee extensors and vertical jump performance. The highest correlations occurred at speeds between 3.14 and 4.2 $rad \cdot s^{-1}$. They found the relationship intriguing since the contraction executed on the isokinetic dynamometer represented an unnatural muscular activity from a functional point of view. They also noted that the electrogoniometrically determined angular velocity for the knee during vertical jumping was 4.4 $rad \cdot s^{-1}$, which was similar to the isokinetic velocities of significance. This observation led to a suggestion that the likelihood of a correlation would improve as the speed of the isokinetic contraction approached that observed in the ballistic movement.

The contribution of muscular strength to successful vertical jump performance is clouded by the general finding that alterations in strength do not correlate well with changes in jump performance. This is true for several variations on this theme: both variables showing an increase but with no correlation (McClements; 1966; Eisenman, 1978); no change in strength despite an improved performance (VanOteghen, 1975); a gain in strength but no change in performance (Ball et al., 1964; Wiater et al., 1984) and a loss in strength which was not correlated to decrements in vertical jump scores (Hakkinen and Komi, 1983; Viitasalo and Aura, 1984).

Numerous authors have examined the effect of various types of resistance training programs on vertical jump performance. An isometric training program using a squat position had no effect upon vertical jumping (Ball et al., 1964). Berger (1963) also found that static contractions resulted in no change, while vertical jump training actually decreased vertical jump performance. Additionally, he noted that two isotonic routines of different intensities produced jump increases. An early study by Chui (1950) determined that a 12 week program of general isotonic exercises increased the vertical jump. Several further studies have also shown that vertical jump performance is increased after completing isotonic training programs (Stevens, 1980; Wathen, 1980; Clutch et al., 1983; Shields et al., 1985), especially when jump training is superimposed (Thorstensson et al., 1976; Eisenman, 1978; Tihanyi, 1984).

Similar results were domonstrated by Hakkinen and Komi (1983) in a study which utilized a force platform to assess the effects of a 16 week progressive isotonic squat program. They noted significant increases in height jumped, as well as average force and mechanical power in the positive work phase of jumps with and without an unweighting phase. No changes were seen for these later two variables in the unweighting and decelerating phases of the jumps. Disagreement is provided by Pipes and Wilmore (1975) and Smith and Melton (1981) who showed no quantifiable changes in vertical jumping from isotonic training. Analogous results were reported by Komi et al. (1982) for a project which compared the effects of heavy-weight, slow-speed isotonic training to a program of light-weight, explosive isotonic work. Over the 16 week duration of the program, both programs produced similar significant increases in isometric strength but no alteration in vertical jump scores. However, the explosive training participants showed a marked decrement in performance midway through the program before recovering to initial levels. It was suggested that the increased fiber areas demonstrated by the heavy resistance group coupled with the enhanced myokinase activity displayed by the explosive training group may have been responsible for this performance difference.

Blattner and Noble (1979) and Clutch et al. (1983) have found that plyometric training produced improvements in vertical jumping ability. Clutch et al. (1983) also noted no difference between the effects of a standard plyometric routine and one which was combined with isotonic weight training. Programs using vertical jumping as the training mode either alone (Clutch et al., 1983) or in conjunction with other training regimens (Thorstensson et al., 1976; Eisenman, 1978; Viitasalo and Aura, 1984) have been shown to elevate vertical jump performance. Neuromuscular factors which have been suggested as being responsible for the vertical jump results observed from isotonic, jump and plyometric training include fast-twitch fiber hypertrophy (Thorstensson et al., 1976), enhanced elastic energy component (Viitasalo and Aura, 1984), augmented neural activation and motor unit recruitment pattern (Wathen, 1980; Hakkinen and Komi, 1983).

Minimal research has been reported concerning the effects of quantifiable isokinetic training upon vertical jump performance. Both VanOteghen (1975) and Counsilman (1976) indicated that both 'low' and 'high' speed isokinetic training produced similar increases in vertical jumping. Blattner and Noble (1979), Stevens (1980) and Wathen (1980) had subjects complete an eight week isokinetic leg thrust training program at variable, unquantified intensities. Both Blattner and Noble (1979) and Stevens (1980) noted an increase in vertical jump while Wathen (1980) saw no significant change. For training, all of these studies utilized the Mini-Gym type of apparatus which basically has either a chain drive or a pulley system with a mechanical speed governor to attempt control of the velocity of movement.

Pipes and Wilmore (1975) found isokinetic training of the knee extensors for eight weeks at velocities of either 0.42 or 2.37 rad·s^{-1} to be equally effective in increasing vertical jump performance. They used the terms low speed and high speed to describe the isokinetic training programs and noted significant improvements in three other skilled performances from the later program. They interpreted these findings as being indicative of a velocity specificity in training, with maximal changes obtainable through training isokinetically at high speed. This study seemed to provide the impetus for both the application of and further research on this concept. Unfortunately, the accuracy of this study has been questioned due to errors in the data analysis (Wilmore, 1979). In contrast, a similar study by Smith and Melton (1981) found greater gains in vertical jumping for high speed as opposed to slow speed isokinetic training. It should be noted that no statistical analysis was provided due to the small group size (n=3) and that the isokinetic training program was conducted over a range of velocities. Shields et al. (1985) also found that an improvement in the vertical jump performance was elicited by a variable isokinetic program where the speed of joint movement was increased throughout each of the eight weeks of the program.

The specificity of velocity principle has led several authors to infer that isokinetic training would be superior to other training modes in eliciting changes in high velocity skilled performances (Pipes and Wilmore, 1975; Sale and MacDougall, 1981; Grimby, 1982). This inference is only partially born out with respect to the enhancement of vertical jump performance. While the studies of Pipes and Wilmore (1975), Stevens (1980) and Smith and Melton (1981) support this contention, those of Blattner and Noble (1979), Wathen (1980) and Shields et al. (1985) do not. Further study is required to clarify this relationship.

The majority of the inconsistencies noted in the reported studies are attributable to differenes and deficiencies in experimental design. Relevant factors include subject selection (age, sex, previous training) quantification of the training programs (training volume, velocity of joint movement, equipment used, and the level and type of concurrent activity) and utilizing quantifiable assessment methodologies (cinematography, force platforms) (Clutch et al., 1983; Hay et al., 1983; Tihanyi, 1984). The necessity to eliminate such sources of variance was demonstrated by Wiater et al. (1984). They used a standard jump and reach test as well as high speed cinematography to evaluate the effects of a ten week isokinatic (hydraulic resistance equipment) training program upon vertical jump performance. For one group, a significant decrease arose from the jump and reach test data but a significant increase was demonstrated cinematographically; which would lead to dramatically different interpretations regarding the effectiveness of the training program. The significant discrepencies noted between the two assessment methodologies led to a recommendation for the use of more sensitive techniques such as biomechanical analyses when examining relationships between training programs and skilled athletic performance. To date, the application of biomechanical techniques for such a purpose has been very limited (Hakkinen and Komi, 1983; Wiater et al., 1984).

There is a paucity of research concerning quantification of the kinetic and kinematic characteristics of the standing vertical jump as well as the neuromuscular mechanisms underlying this performance. This is surprising as the standing vertical jump in a variety of forms has been extensively employed for evaluative and predictive purposes in physical education and sport since the development of the "Sargent Jump Test" (Sargent, 1921). The literature which does exist is both weak in design and lacking in unifying elements. Therefore, a review provides discrete bits of information rather than a coordinated body of knowledge.

From a biomechanical perspective, the maximum displacement which the center of mass can achieve in a vertical jump is determined by both the vertical velocity (speed and angle) at take-off and the height of the center of mass at take-off (Hay, 1975, 1978). The vertical velocity is dependent upon maximizing the magnitude of the vertical impulses generated by the various body segments. This is achieved through the appropriate coordination of the sequencing of the segments and the forces generated by their attendant muscle groups. Vertical impulse is the product of the magnitude and duration of the vertical force component. The greatest vertical impulse, and consequently vertical take-off velocity, occurs when both force and time are maximized. The anatomy, physiology and biomechanics of the human body account for the ultimate limits to which these two factors may be maximized as well as the lack of a positive linear relationship between them. Achieving maximum height of the center of mass at take-off for a two foot standing vertical jump would involve optimal synchronization of motor unit recruitment to allow the coordination of the body segments so that they would complete extension of the legs and arms, with the trunk and head being erect, exactly at take-off (Payne et al., 1968; Hay, 1978).

The degree to which the knees are flexed immediately prior to the commencement of leg extension has been traditionally accepted as being closely related to the vertical force generated from the extensor muscles. The degree of knee flexion for the vertical block jump in volleyball has most often been recommended at 1.57 radians with the lack of adequate performance of this skill being attributed to an inability to achieve this degree of flexion (Scates, 1972; Canadian Volleyball Association, 1978; Bratton and Lefroy, 1980). Angles of about 1.83, 1.57 and 1.48 radians have also been suggested for the knee, hip and ankle joints for this skill (Cardinal and Pelletier; 1983). Few research reports exist which describe the angles of flexion for the knee, hip and ankle joints for standing vertial ju[illegible] Martin and Stull (1969) measured the height reached by male subjects who performed standing vertical jumps from static starting positions of 1.13, 1.57 and 2.01 radians of knee extension. They found significantly better performance from the 2.01 radian starting position and noted that their results may not be applicable to vertical jumps which include an unweighting phase. For an undefined vertical jump performed by males, a knee angle of 1.66 radians and a hip angle of 1.76 radians may be calculated from the data of Eckert (1968~~b~~) when the angles at take-off are assumed to be 3.14 radians. Adrian and

Laughlin (1983) reported that the maximal angle of flexion at the knee ranged from 1.05 to 2.09 radians with a mean of 1.73 radians for a group of skilled females performing a stationary volleyball block jump. Their analysis of this movement also revealed that the knee underwent 0.16 radians of extension after take-off.

Eckert (1968b) studied the effects of added weight upon the angular velocity and range of motion at the hip, knee and ankle joints during vertical jumps with an arm swing in a group of skilled male athletes. Increasing weight resulted in increased ranges and time of joint motion with consequent decreases in angular velocity. For the hip, knee and ankle the mean angular velocities were found to be 5.8, 7.5, 5.9 rad·s^{-1} whilst the maximal angular velocities were calculated at 11.3, 16.0, 18.7 rad·s^{-1} respectively. A similar study by Eckert (1968a) included skilled female subjects and revealed comparable results between the sexes for the maximal angular velocities generated at each joint. It was noted, however, that the range of motion at the hip and knee joints was significantly smaller for the female subjects.

Desipres (1976) analyzed the performance of six subjects from three age groups (13, 17 and 21 yrs) on a standing vertical jump which allowed an unrestricted armswing. The angular velocity at the knee was observed to decrease

(6.71, 6.26, 5.36 rad$\cdot$s^{-1}) with age. The average vertical velocity and ground reaction force were determined as 2.90 m$\cdot$s^{-1} and 1,244 N respectively. The kinetics of the stationary volleyball block jump were characterized by Adrian and Laughlin (1983) using 15 female volleyball players. The average peak vertical force was 1872 N with the height of rise of center of mass being 28 cm. The mean angular velocity of the knee during the extension phase was determined to be 22 rad$\cdot$s^{-1}. A direct relationship was infered between leg extension velocity and both vertical force and the center of mass displacement.

Perrine et al. (1978) compared the isolated power capacities and power transformation characteristics of the leg extensors in vertical jumping using ten skilled and ten unskilled subjects of both sexes. Only moderate correlations were found between jump height and the force values generated at the start of extension (r=0.65), at peak force (r=0.66) and at peak power (r=0.62) during the positive impulse phase of the jump performance. The height jumped was highly correlated to the peak instantaneous power (r=0.85) and the vertical velocity of the hip point (r=0.87). Also, the peak power output as measured on an isokinetic leg press dynamometer displayed a high correlation (r=0.88) to the height jumped.

Coutts (1978a,b) in studying the standing vertical jump with an arm swing (Sargent jump) versus one with a restricted arm swing (volleyball block jump) found ground reaction forces of 1163 N vs 1162 N and 941 N vs 899 N, respectively, for skilled males and females. No significant differences were noted in peak force, positive impulse time or the positive impulse between the two types of jumps. However, the height achieved in the restricted arm swing jump was significantly less (3.5%) than that of the Sargent jump as determined from force platform measurement of time in the air. He attributed the difference in jump height to a reduced movement efficiency rather than a decrease in the vertical impulse. It was suggested that movement efficiency would be enhanced by reducing both the impulse time and ground force during the unweighting phase thus allowing a better utilization of stored series elastic energy. The observed sex difference in vertical jump performance was attributed to the assumed greater strength to weight ratio and movement efficiency of the males.

Numerous researchers (Cavagna et al., 1971; Tveit, 1976; Komi and Bosco, 1977, 1978; Bosco and Komi, 1979a; Bosco and Viitasalo, 1982) have found greater vertical force, positive impulse, vertical velocity at take-off, integrated electromyographic activity and height of rise of center of mass when a prepatory countermovement (ie. unweighting phase) was allowed in the vertical jump performance. These increments have been ascribed to the contribution of stored energy by the series elastic component of the muscle (Cavagna et al., 1971; Asmussen and Bonde-Petersen, 1974; Komi and Bosco, 1977, 1978). An efficiency factor has been implied by Tveit (1976) who determined that the horizontal forces generated in a standing vertical jump were reduced, and therefore the coordination of the performance enhanced, when an unweighting phase was allowed. He also noted that no significant performance increments resulted from a standardized five minute bicycle ergometer warm-up prior to jumping.

Several methodological approaches have been utilized to determine the sequencing and proportional contribution of the various muscle groups to standing vertical jump performance. After determining the segmental inertial forces in vertical jumps with an arm swing, Miller and East (1976) implicated the knee and hip extensors as the major contributors to the weighting phase impulse. From electromyographic recordings Desipres (1976) determined that the rank order of muscular involvement during the positive impulse phase of the vertical jump was as follows: vasti, gastrocnemius, rectus femoris, biceps femoris, soleus and tibialis anterior. Both the observed ground reaction force (r=0.22) and impulse (r=0.36) were stated as being correlated to the total liberated muscle potential. Luhtanen and Komi (1978) undertook a comparative analysis of whole body and isolated segmental performances to estimate the contribution of various body segments to the forces acting upon the whole body center of mass in the standing vertical jump with an arm swing. They determined that the component contributions to maximal vertical take-off velocity were as follows: knee extension 56%, plantar flexion 22%, trunk extension 10%, arm swing 10% and head extension 2%. Analysis of whole body performances revealed that the average vertical velocity achieved at take-off was only 76% of the theoretical maximum calculated from the segmental analyses. It was determined that this summation could be increased to 84% through optimal timing of the segmental contributions. A work-energy approach was utilized by Hubley and Wells (1983) to determine the contributions provided by muscle groups acting at individual joints to vertical jump performance. The results indicated that for both static and unweighting phase jumps, the average relative contributions of the extensor muscle groups for the knee, hip and ankle were 49, 28 and 23 percent respectively. Large variations in joint contributions were noted between individuals which demonstrated that while the performance may be similar, the summation patterns used to achieve that performance may be quite different. A three segment model (head-arms-trunk, thighs, and shanks) was used by Hudson and Owen (1983) to evaluate segmental coordination patterns in the vertical jump. Only one subject exhibited a sequential pattern while six demonstrated a simultaneous pattern. However, the majority of the subjects employed a pattern which saw additional knee flexion and ankle dorsi-flexion after the initiation of hip extension. A significant correlation was noted between the synchronization of movement and the use of stored elastic energy. This finding supported their previous study (Hudson and Owen, 1981) which indicated that the ability to coordinate body segments rather than jumping ability was related to the utilization of stored elastic energy. From these results they suggested that performance ability is a poor criterion for assessing human movement techniques.

While the review has drawn several pieces of the puzzle together the picture is far from complete. Further studies stressing proper design and quantification must be undertaken to provide a clear understanding of the interactions required between neuromuscular physiology, resistance training and skilled athletic performance if training programs and consequent performances are to be optimized.

APPENDIX B

PILOT STUDY

A pilot project was conducted several weeks in advance of the actual study. The purposes of the pilot were to:

1. determine the efficacy, consistency and practicality of the testing protocols and equipment;
2. determine the efficacy, consistency and practicality of the training protocols and equipment;
3. determine the efficacy, consistency and practicality of the techniques used for initial data reduction.

Six male athletes were recruited and subjected to the proposed testing and training protocols on separate days. Based upon an evaluation of the results and feedback obtained from these sessions, revisions were made to the experimental procedures. These changes are noted below. Subsequently four male subjects who had not participated in the first stage of the pilot project, along with two subjects who had participated, were evaluated using the revised protocols. None of the subjects from the pilot project were used as subjects in the actual study. Where deemed necessary, a test-retest procedure was used to determine reliability coefficents.

The following modifications were made to the experimental procedures and equipment from the results obtained on the pilot project:

Area of Concern	Modifications
VBJ test set-up	Platform around force plate; use black background; place reference tree behind subject on floor aligned in their mid-saggital plane.
VBJ test protocol	Have subjects perform VBJ in an athletic supporter to ensure visibility of segment endpoints; to standardize VBJ the subject must keep their head up by looking at the target throughout the movement.
Force platform capabilities	No modification; forces produced in VBJ were within range used for static calibration; test-retest status calibrations at the commencement and end of each pilot session demonstrated linearity in the X axis with r=0.986 to 0.993.
VBJ data reduction	Use only right limb segment endpoints for analysis due to symmetry of VBJ; test-retest reliability for individual frames resulted in r values from 0.99983 to 0.99997.
IKE and IPF test protocols	For IKE, stabilize body using padded three point auto racing harness and second dynamometer; perform IPF in supine position with padded belts for

	stabilization; damping to be set at 2 for all testing.
IKE and IPF data reduction	Test-retest reliability for digitized test and calibration traces resulted in r values from 0.964 to 0.991.
IKE and IPF training protocols	High velocity training setting for IPF reduced to 4.0 $\text{rad}\cdot\text{s}^{-1}$ as most subjects could not maintain the production of measurable force at initial setting of 5.0 $\text{rad}\cdot\text{s}^{-1}$ for the duration of the bout.

APPENDIX C

TABLE 11. Activity profile summary for the three groups.

Subject	Pre-Training Activity	Activity During Training Program	Weekly Volume[a]			Change	Illness
			I	D	F		
1	running	running	M	60 min	3x/wk		
	weight lifting (upper body)	weight lifting (upper body)	M	30 min	2x/wk		
2	soccer	soccer	H	2 hr	3x/wk		
		weight lifting (upper body)	H	60 min	1x/wk		
3	softball	softball	L	90 min	2x/wk	first 2 weeks (league finished)	cold
	running	running	M	15 min	4x/wk		
	cycling	weight lifting (upper body)	M	60 min	2x/wk		
4	weight lifting badminton	weight lifting (upper body)	M	60 min	1x/wk		
	running	running	H	15 min	1x/wk		
5	cycling	cycling	M	40 min	3x/wk		
6	calisthenics	weight lifting (upper body)	M	60 min	5x/wk		
7	running weight lifting	running/ calisthenics	M	60 min	4x/wk		cold
	judo	judo	M-H	90 min	2x/wk		
8	running	cycling	L	15 min	3x/wk		flu
		weight lifting (upper body)	M	45 min	2x/wk		
9	running	running	M	50 min	4x/wk		
	weight lifting	weight lifting	M	60 min	3x/wk		
10	cycling	cycling	M-H	90 min	4x/wk		
	dryland skiing	dryland skiing	M	60 min	3x/wk		
	weight lifting	weight lifting	M-H	60 min	3x/wk		

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[a] I indicates intensity as being either high (H), moderate (M) or low (L) in effort; D indicates duration; F indicates frequency

TABLE 11. Activity profile summary for the three groups (continued).

Subject	Pre-Training Activity	Activity During Training Program	Weekly Volume[a]			Change	Illness
			I	D	F		
11	weight lifting (upper body)	weight lifting (upper body)	M	60 min	2x/wk		
		run/cycle/swim	M-H	30 min	2x/wk		
12	running	running/ calisthenics	H	45 min	6x/wk	reduced volume last 2 weeks	injury left knee
13	rugby	rugby	M	60 min	2x/wk		cold/ flu
14	weight lifting	weight lifting (upper body)	H	30 min	3x/wk	decrease in F	
	cycling	running/ cycling	M	30 min	4x/wk		
15	cycling	baseball	M-H	2 hr	5x/wk		
		cycling	L-M	30 min	5x/wk		
16	training - variety of activities	cycling	M	15 min	5x/wk		
		running - interval	M-H	60 min	4x/wk		
17	running walking	running	M-H	90 min	6x/wk		
18	judo	judo	L-M	90 min	2x/wk		
19	running weight lifting Occasionally	weight lifting (upper body)	L-M	60 min	3x/wk		
20	running weight lifting	weight lifting (upper body)	H	60 min	2x/wk		flu
		running	M	30 min	2x/wk		

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[a] I indicates intensity as being either high (H), moderate (M) or low (L) in effort; D indicates duration; F indicates frequency

TABLE 11. Activity profile summary for the three groups (continued).

Subject	Pre-Training Activity	Activity During Training Program	Weekly Volume[a] I	D	F	Change	Illness
21	running/cycling	running/cycling	H	2 hr	2x/wk		
	weight lifting	weight lifting	M	30 min	2x/wk		
22	racquet sport	running	L-M	20 min	7x/wk		cold
	running	weight lifting (upper body)	M-H	45 min	3x/wk	begun in last 2 weeks	
23	dirt bike	dirt bike	M-	75 min	3x/wk		
	racquet sports	racquet sports	M-	75 Min	3x/wk		
24	weight lifting	calisthenics	M	90 min	3x/wk		
25	tennis	tennis	M	2 hr	1x/wk		
	golf	golf	L	5 hr	2x/wk		
26	running	running/ calisthenics	M-H	60 min	4x/wk		
27	rugby	rugby	M	90 min	3x/wk		flu
	weight lifting (upper body)	weight lifting (upper body)	H	90 min	3x/wk		
28	running	running/ calisthenics	M-H	90 min	5x/wk	reduced volume last 2 weeks	flu
	badminton						
29	running	running	M	25 min	2x/wk		
30	squash	dancing	M	3 hr	1x/wk		
	dancing						

[a] I indicates intensity as being either high (H), moderate (M) or low (L) in effort; D indicates duration; F indicates frequency

APPENDIX D

TABLE 12. Descriptive physica[illegible]cteristic data for the three groups.

Group	Subject	AGE (yrs)	MASS (kg) Pre	MASS (kg) Post	LBM (kg) Pre	LBM (kg) Post	PBF (%) Pre	PBF (%) Post
HVG	1	21.8	76.7	75.8	68.71	69.28	10.42	8.60
	2	22.0	69.4	70.0	64.14	64.80	7.57	7.43
	3	23.0	70.3	70.3	58.12	58.38	17.33	17.02
	4	23.3	78.7	77.5	66.22	65.45	15.85	15.55
	5	20.3	73.7	74.2	66.50	66.10	9.77	10.92
	6	23.1	87.5	85.4	72.44	72.40	17.21	15.22
	7	20.4	60.3	61.1	57.77	58.31	4.19	4.56
	8	24.0	71.2	73.0	68.43	69.15	3.89	5.28
	9	29.5	92.2	88.8	81.03	79.32	12.12	10.68
	10	22.8	70.1	71.4	63.55	66.44	9.35	6.95
	$\bar{X}$	23.0	75.0	74.8	66.69	66.96	10.77	10.22
	SEM	0.8	2.9	2.5	2.15	1.97	1.55	1.41
LVG	11	17.4	64.8	65.5	57.91	60.20	10.64	8.10
	12	23.8	61.6	60.7	56.68	56.04	7.99	7.68
	13	21.8	75.5	75.9	61.96	61.87	17.93	18.49
	14	16.2	81.8	81.9	73.63	73.58	9.98	10.16
	15	22.0	85.1	83.1	73.49	74.72	13.65	10.08
	16	20.8	72.8	73.1	68.07	68.81	6.49	5.87
	17	22.1	66.6	66.7	59.90	59.61	10.06	10.63
	18	31.5	76.2	76.4	64.05	64.79	15.94	15.19
	19	20.2	77.5	78.8	65.03	65.74	16.09	16.58
	20	22.3	85.5	85.8	77.97	76.63	8.81	10.67
	$\bar{X}$	21.8	74.7	74.8	65.87	66.20	11.76	11.34
	SEM	1.3	2.6	2.6	2.29	2.23	1.23	1.30
CONG	21	24.7	77.3	76.2	65.53	65.40	15.23	14.17
	22	23.7	66.1	65.8	57.53	57.27	12.97	12.96
	23	25.3	86.5	87.0	71.50	72.04	17.34	17.20
	24	22.4	79.5	78.5	66.90	66.24	15.85	15.62
	25	21.5	67.2	66.7	62.92	60.50	6.37	9.30
	26	26.8	69.4	69.6	60.36	61.09	13.03	12.23
	27	24.0	94.6	95.1	77.14	76.92	18.46	19.12
	28	21.7	68.3	69.1	64.88	66.39	5.00	3.91
	29	27.0	78.3	78.2	65.02	64.15	16.97	17.96
	30	22.3	73.5	71.7	67.34	65.82	8.39	8.21
	$\bar{X}$	23.9	76.1	75.8	65.91	65.58	12.96	13.07
	SEM	0.6	2.9	3.0	1.79	1.74	1.52	1.52

TABLE 13. Relative peak torque data for the knee at the seven selected velocities for the three groups (in $Nm \cdot kg^{-1}$).

		KRPT0		KRPT0.5		KRPT1		KRPT2	
Group	Subject	Pre	Post	Pre	Post	Pre	Post	Pre	Post
HVG	1	3.69	3.80	3.49	4.19	3.17	3.50	2.41	2.57
	2	3.61	3.68	3.39	3.61	3.29	3.51	2.77	2.92
	3	3.03	3.39	3.17	3.32	2.75	2.90	2.33	2.49
	4	3.12	3.62	3.40	3.58	3.25	3.20	2.60	2.48
	5	2.62	2.84	3.26	3.28	2.62	2.57	2.37	2.36
	6	2.86	3.17	3.23	3.37	2.95	3.08	2.44	2.50
	7	4.07	3.77	3.21	3.94	2.80	3.41	2.53	2.88
	8	3.50	3.33	3.73	4.11	3.24	3.33	2.58	2.70
	9	3.01	3.27	3.25	3.60	2.99	3.30	2.39	2.56
	10	3.50	3.33	3.79	3.79	3.18	3.33	2.87	2.95
	$\bar{x}$	3.30	3.42	3.39	3.68	3.02	3.21	2.53	2.64
	SEM	.14	.10	.07	.10	.08	.29	.06	.07
LVG	11	3.79	4.35	3.60	3.94	2.60	3.71	2.43	2.78
	12	3.55	4.62	3.60	4.86	3.39	4.21	2.92	3.15
	13	3.12	2.91	3.32	3.56	3.12	3.63	2.59	2.94
	14	3.03	3.39	3.85	4.03	3.40	3.60	2.68	2.79
	15	3.38	3.67	3.41	4.30	3.15	3.82	2.62	2.92
	16	3.80	4.31	4.21	4.44	3.77	4.07	3.12	3.22
	17	2.94	3.49	3.69	4.54	2.98	3.76	2.44	2.88
	18	2.93	3.41	2.67	3.64	2.77	3.44	2.39	2.63
	19	2.69	3.05	3.23	3.43	3.23	3.37	2.37	2.33
	20	3.51	4.34	3.77	4.05	3.42	3.99	2.96	3.03
	$\bar{x}$	3.27	3.75	3.53	4.08	3.18	3.76	2.65	2.87
	SEM	.12	.19	.13	.15	.11	.09	.08	.08
CONG	21	3.37	3.35	3.27	3.19	2.63	2.64	2.13	2.18
	22	3.23	3.20	3.23	3.58	2.96	3.20	2.42	2.66
	23	2.82	2.85	3.07	2.94	2.78	2.76	2.35	2.42
	24	3.43	3.38	2.96	2.94	2.81	3.00	2.40	2.43
	25	3.10	3.27	3.06	2.57	2.77	2.64	2.27	2.38
	26	3.74	3.74	4.28	4.38	3.42	3.38	2.85	2.81
	27	3.88	3.44	3.38	3.36	3.15	2.79	2.39	2.14
	28	3.74	3.19	3.45	3.70	3.41	3.52	2.76	2.67
	29	4.21	3.84	3.45	3.58	3.36	3.33	2.53	2.54
	30	2.79	3.11	2.60	2.80	2.70	2.87	2.43	2.46
	$\bar{x}$	3.43	3.34	3.27	3.30	3.00	3.01	2.45	2.47
	SEM	.15	.09	.14	.17	.10	.10	.07	.07

TABLE 13. Relative peak torque data for the knee at the seven selected velocities for the three groups (in Nm·kg^{-1}) (continued).

		KRPT3		KRPT4		KRPT5	
Group	Subject	Pre	Post	Pre	Post	Pre	Post
HVG	1	1.97	2.22	1.70	2.01	1.47	1.75
	2	2.05	2.13	1.77	1.95	1.52	1.70
	3	1.90	2.31	1.71	2.10	1.41	1.73
	4	2.14	2.34	1.80	2.05	1.50	1.79
	5	2.07	2.12	1.82	1.97	1.36	1.70
	6	2.13	2.16	1.71	1.84	1.42	1.57
	7	2.10	2.31	1.95	2.09	1.60	1.81
	8	2.11	2.34	1.69	2.02	1.57	1.80
	9	1.87	2.07	1.82	2.00	1.48	1.79
	10	2.05	2.12	1.91	2.21	1.66	1.96
	$\bar{x}$	2.04	2.21	1.79	2.02	1.50	1.76
	SEM	.03	.03	.03	.03	.03	.03
LVG	11	1.93	2.21	1.59	1.91	1.32	1.44
	12	2.31	2.57	2.08	2.12	1.72	1.68
	13	2.20	2.48	1.89	1.99	1.63	1.80
	14	2.17	2.26	1.85	1.94	1.53	1.64
	15	2.03	2.48	1.73	2.09	1.49	1.88
	16	2.53	2.70	2.00	2.22	1.83	2.02
	17	1.92	2.31	1.77	1.95	1.51	1.71
	18	1.94	2.14	1.50	1.75	1.37	1.64
	19	1.98	2.11	1.65	1.83	1.49	1.54
	20	2.29	2.47	2.10	2.10	1.75	1.72
	$\bar{x}$	2.13	2.37	1.82	1.99	1.56	1.71
	SEM	.06	.06	.06	.05	.05	.05
CONG	21	1.88	1.87	1.59	1.45	1.33	1.33
	22	2.14	2.19	1.88	1.90	1.54	1.70
	23	1.88	2.01	1.65	1.72	1.35	1.35
	24	2.09	2.20	1.82	1.72	1.47	1.50
	25	1.96	2.01	1.92	1.84	1.61	1.58
	26	2.24	2.21	1.91	1.94	1.59	1.60
	27	1.93	1.83	1.68	1.49	1.26	1.04
	28	2.27	2.28	1.80	1.49	1.47	1.40
	29	2.30	2.33	1.88	1.90	1.66	1.70
	30	2.23	2.40	1.96	2.04	1.72	1.73
	$\bar{x}$	2.09	2.13	1.81	1.75	1.50	1.49
	SEM	.05	.06	.04	.07	.05	.07

TABLE 14. Relative peak power data for the knee at the six selected velocities for the three groups (in $Nm \cdot kg^{-1} \cdot s^{-1}$).

		KRPP0.5		KRPP1		KRPP2	
Group	Subject	Pre	Post	Pre	Post	Pre	Post
HVG	1	1.84	2.14	3.30	3.68	4.91	5.42
	2	1.83	1.90	3.57	3.68	5.49	5.90
	3	1.62	1.75	2.88	3.07	4.86	5.16
	4	1.84	1.96	3.41	3.35	5.38	5.16
	5	1.67	1.84	2.76	2.76	4.75	4.92
	6	1.61	1.87	3.07	3.26	4.89	5.03
	7	1.65	2.09	3.07	3.69	5.14	5.94
	8	1.95	2.27	3.45	3.54	5.26	5.64
	9	1.70	1.91	3.29	3.63	5.00	5.35
	10	1.99	1.95	3.35	3.56	5.96	6.05
	$\bar{x}$	1.77	1.97	3.21	3.42	5.16	5.46
	SEM	.04	.05	.08	.10	.12	.13
LVG	11	1.85	2.09	2.78	3.98	4.88	5.64
	12	1.87	2.59	3.53	4.56	5.90	6.57
	13	1.76	1.97	3.16	3.82	5.30	6.09
	14	2.00	2.12	3.64	3.81	5.44	5.64
	15	1.83	2.73	3.26	3.96	5.32	6.06
	16	2.31	2.37	4.01	4.29	6.44	6.70
	17	1.98	2.39	3.17	3.90	4.92	5.85
	18	1.36	1.94	2.81	3.66	4.86	5.44
	19	1.70	1.90	3.29	3.62	4.83	4.80
	20	1.98	2.28	3.59	4.45	5.89	6.19
	$\bar{x}$	1.86	2.24	3.32	4.00	5.38	5.90
	SEM	.08	.09	.12	.10	.17	.18
CONG	21	1.72	1.66	2.81	2.86	4.38	4.54
	22	1.68	1.86	3.06	3.32	4.96	5.51
	23	1.56	1.57	2.96	2.90	4.79	4.81
	24	1.55	1.56	3.01	3.18	4.81	4.96
	25	1.57	1.33	2.86	2.76	4.66	4.91
	26	2.36	2.26	3.64	3.52	5.74	5.67
	27	1.74	1.73	3.24	2.95	5.02	4.41
	28	1.80	2.00	3.62	3.90	5.67	5.38
	29	1.78	1.93	3.57	3.53	5.29	5.09
	30	1.33	1.43	2.82	3.05	5.01	4.92
	$\bar{x}$	1.71	1.73	3.16	3.20	5.03	5.02
	SEM	.08	.09	.11	.12	.14	.13

TABLE 14. Relative peak power data for the knee at the six selected velocities for the three groups (in Nm·kg^{-1}·s^{-1}) (continued).

		KRPP3		KRPP4		KRPP5	
Group	Subject	Pre	Post	Pre	Post	Pre	Post
HVG	1	5.99	6.96	6.84	8.07	7.41	8.77
	2	6.34	6.49	6.95	7.81	7.88	8.57
	3	5.99	7.01	6.78	8.50	7.07	8.58
	4	6.71	7.16	7.37	8.30	7.52	9.02
	5	6.29	6.65	7.28	7.93	6.79	8.58
	6	6.45	6.52	6.80	7.33	7.11	7.89
	7	6.66	7.16	7.91	8.31	8.04	9.32
	8	6.41	7.13	6.70	8.04	7.81	9.00
	9	5.82	6.31	7.33	8.14	7.50	9.05
	10	6.27	6.47	7.66	8.94	8.36	9.88
	$\bar{x}$	6.29	6.79	7.16	8.14	7.55	8.87
	SEM	.09	.10	.13	.14	.15	.17
LVG	11	5.96	6.76	6.38	7.71	6.66	7.24
	12	7.11	8.17	8.44	8.55	8.75	8.22
	13	6.76	8.00	7.50	7.98	8.19	8.89
	14	6.59	6.77	7.49	7.81	7.61	8.22
	15	6.25	7.53	6.98	8.31	7.41	9.35
	16	7.72	8.29	8.02	8.73	9.13	10.11
	17	5.97	7.07	7.06	7.82	7.59	8.63
	18	6.02	6.69	6.02	7.09	6.82	8.10
	19	6.13	6.52	6.58	7.30	7.48	7.68
	20	7.15	7.83	8.46	8.67	8.73	8.57
	$\bar{x}$	6.57	7.36	7.29	8.00	7.84	8.50
	SEM	.19	.21	.27	.18	.26	.26
CONG	21	5.66	5.59	6.49	5.86	6.58	6.67
	22	6.53	6.55	7.52	7.68	7.67	8.44
	23	5.65	6.08	6.61	6.92	6.81	6.72
	24	6.32	6.71	7.34	6.90	7.40	7.55
	25	5.95	6.15	7.65	7.39	8.00	7.88
	26	6.91	6.90	7.58	7.70	8.04	8.11
	27	5.95	5.81	6.73	5.84	6.42	5.30
	28	6.90	7.06	7.18	6.16	7.39	7.12
	29	6.92	7.10	7.70	7.59	8.35	8.58
	30	6.89	7.47	7.93	8.33	8.56	8.60
	$\bar{x}$	6.37	6.54	7.27	7.04	7.52	7.50
	SEM	.17	.19	.16	.27	.23	.33

TABLE 15. Relative peak torque data for the ankle at the seven selected velocities for the three groups (in Nm·kg^{-1}).

		ARPT0		ARPT0.5		ARPT1		ARPT2	
Group	Subject	Pre	Post	Pre	Post	Pre	Post	Pre	Post
HVG	1	2.70	3.12	1.78	1.98	1.31	1.59	.86	1.16
	2	2.54	2.44	1.54	1.56	1.11	1.15	.80	.71
	3	2.31	2.50	1.01	1.75	.90	1.29	.51	.78
	4	2.88	2.75	1.10	1.34	1.04	1.36	.69	.98
	5	2.47	2.22	1.09	1.15	1.01	1.17	.82	.89
	6	2.17	2.44	1.03	1.32	.71	1.03	.72	.97
	7	2.92	2.84	1.91	1.93	1.34	1.48	.99	1.01
	8	2.89	3.06	2.04	1.97	1.46	1.43	.91	.97
	9	2.81	3.02	1.83	2.11	1.40	1.62	.95	1.13
	10	3.11	2.64	2.05	1.96	1.61	1.44	1.06	.99
	$\bar{X}$	2.68	2.70	1.54	1.71	1.19	1.36	.83	.96
	SEM	.09	.10	.14	.11	.09	.06	.05	.04
LVG	11	3.14	3.20	1.82	2.01	1.59	1.65	1.07	1.06
	12	2.29	2.78	1.27	1.68	1.00	1.41	.67	.65
	13	2.22	2.55	1.23	1.63	.90	1.36	.79	1.09
	14	2.50	2.45	1.24	1.47	.99	1.30	.71	.79
	15	2.86	3.16	1.79	2.28	1.33	1.54	.95	1.07
	16	2.65	3.07	1.76	2.10	1.39	1.65	.93	1.07
	17	2.83	3.01	1.92	1.99	1.28	1.51	.95	1.04
	18	2.57	2.78	1.77	2.00	1.42	1.70	.94	1.12
	19	2.93	3.10	1.39	1.65	1.12	1.53	.77	.93
	20	2.81	2.98	1.57	1.86	1.32	1.53	.86	1.09
	$\bar{X}$	2.68	2.91	1.58	1.87	1.23	1.52	.86	.99
	SEM	.09	.08	.09	.08	.07	.04	.04	.05
CONG	21	2.39	2.62	1.70	1.64	1.20	1.17	.71	.81
	22	2.18	2.43	1.50	1.53	1.29	1.34	.86	.92
	23	2.18	2.31	1.43	1.47	1.12	1.18	.72	.71
	24	2.04	2.02	1.08	1.15	.80	.88	.37	.39
	25	2.97	3.14	1.46	1.78	1.16	1.25	.85	.87
	26	2.98	3.19	1.71	1.78	1.35	1.37	.93	.98
	27	2.48	2.54	1.35	1.59	1.11	1.15	.73	.70
	28	2.80	2.35	1.54	1.58	1.29	1.31	.73	.72
	29	2.55	2.47	1.47	1.27	1.05	1.08	.67	.73
	30	2.48	2.72	1.54	1.71	1.06	1.05	.42	.61
	$\bar{X}$	2.50	2.58	1.48	1.55	1.14	1.18	.70	.74
	SEM	.10	.11	.06	.07	.05	.05	.06	.05

TABLE 15. Relative peak torque data for the ankle at the seven selected velocities for the three groups (in Nm·kg^{-1}) (continued).

Group	Subject	ARPT3		ARPT4		ARPT5	
		Pre	Post	Pre	Post	Pre	Post
HVG	1	.46	.85	.31	.57	.22	.25
	2	.44	.49	.26	.34	.13	.17
	3	.41	.51	.30	.34	.09	.13
	4	.63	.85	.40	.56	.27	.34
	5	.52	.54	.38	.38	.28	.26
	6	.51	.67	.34	.40	.19	.19
	7	.82	.79	.50	.49	.41	.36
	8	.73	.70	.37	.37	.28	.25
	9	.58	.80	.44	.57	.21	.28
	10	.83	.64	.54	.45	.36	.31
	$\bar{x}$	.59	.68	.38	.45	.24	.25
	SEM	.05	.04	.03	.03	.03	.02
LVG	11	.77	.72	.55	.43	.40	.30
	12	.48	.38	.32	.28	.16	.14
	13	.59	.85	.32	.38	.27	.27
	14	.59	.57	.35	.30	.19	.19
	15	.61	.73	.39	.26	.30	.19
	16	.65	.75	.42	.38	.35	.29
	17	.63	.80	.42	.41	.25	.29
	18	.62	.73	.31	.40	.28	.26
	19	.54	.74	.37	.37	.27	.20
	20	.58	.62	.29	.27	.17	.19
	$\bar{x}$	.61	.69	.37	.35	.26	.23
	SEM	.02	.04	.02	.02	.02	.02
CONG	21	.53	.52	.34	.32	.22	.19
	22	.61	.75	.47	.36	.30	.30
	23	.38	.32	.27	.23	.16	.18
	24	.18	.19	.07	.08	.04	.02
	25	.49	.48	.41	.39	.32	.26
	26	.42	.48	.27	.33	.17	.18
	27	.40	.31	.30	.28	.19	.18
	28	.56	.44	.36	.17	.23	.09
	29	.37	.37	.12	.19	.09	.18
	30	.38	.29	.27	.22	.09	.08
	$\bar{x}$	.43	.41	.29	.26	.18	.17
	SEM	.04	.05	.04	.03	.03	.03

TABLE 16. Relative peak power data for the ankle at the six selected velocities for the three groups (in $Nm \cdot kg^{-1} \cdot s^{-1}$).

		ARPP0.5		ARPP1		ARPP2	
Group	Subject	Pre	Post	Pre	Post	Pre	Post
HVG	1	.94	1.07	1.38	1.68	1.79	2.38
	2	.78	.80	1.19	1.17	1.63	1.42
	3	.50	.96	.96	1.37	1.03	1.62
	4	.55	.70	1.23	1.45	1.45	1.99
	5	.58	.61	1.01	1.26	1.65	1.81
	6	.52	.69	.75	1.08	1.44	1.93
	7	1.01	.98	1.45	1.50	2.05	2.05
	8	1.04	1.07	1.48	1.53	1.81	1.95
	9	.93	1.10	1.50	1.71	1.98	2.39
	10	1.04	1.02	1.62	1.55	2.18	2.07
	$\bar{x}$	.79	.90	1.26	1.43	1.70	1.96
	SEM	.07	.06	.09	.07	.11	.10
LVG	11	.96	1.05	1.73	1.75	2.12	2.16
	12	.65	.92	1.07	1.59	1.39	1.32
	13	.66	.96	.95	1.47	1.58	2.26
	14	.62	.74	1.05	1.41	1.43	1.58
	15	.92	1.25	1.34	1.62	1.88	2.21
	16	.94	1.06	1.50	1.72	1.88	2.20
	17	1.01	1.05	1.40	1.58	1.95	2.13
	18	.93	1.01	1.48	1.74	1.95	2.34
	19	.74	.85	1.13	1.59	1.57	1.93
	20	.84	.98	1.36	1.62	1.73	2.35
	$\bar{x}$	.83	.99	1.30	1.61	1.75	2.05
	SEM	.05	.04	.08	.03	.08	.11
CONG	21	.89	.83	1.32	1.27	1.43	1.64
	22	.79	.83	1.39	1.45	1.76	1.89
	23	.75	.82	1.20	1.17	1.47	1.45
	24	.54	.58	.86	.93	.75	.79
	25	.74	.91	1.20	1.31	1.74	1.77
	26	.92	.96	1.46	1.50	1.91	1.92
	27	.74	.86	1.15	1.25	1.50	1.56
	28	.80	.84	1.31	1.43	1.47	1.46
	29	.73	.64	1.09	1.15	1.32	1.47
	30	.80	.90	1.01	1.11	.85	1.20
	$\bar{x}$	.77	.82	1.20	1.26	1.42	1.51
	SEM	.03	.04	.06	.06	.12	.11

TABLE 16. Relative peak power data for the ankle at the six selected velocities for the three groups (in Nm·kg^{-1}·s^{-1}) (continued).

		ARPP3		ARPP4		ARPP5	
Group	Subject	Pre	Post	Pre	Post	Pre	Post
HVG	1	1.39	2.55	1.25	2.30	1.07	1.23
	2	1.33	1.51	1.04	1.37	.62	.85
	3	1.23	1.51	1.21	1.36	.48	.68
	4	1.92	2.56	1.62	2.27	1.34	1.68
	5	1.58	1.66	1.50	1.54	1.40	1.33
	6	1.57	2.01	1.35	1.60	.95	.94
	7	2.54	2.45	2.01	1.98	2.04	1.79
	8	2.21	2.14	1.47	1.50	1.43	1.27
	9	1.82	2.45	1.79	2.29	1.08	1.47
	10	2.55	1.95	2.18	1.78	1.81	1.56
	$\bar{x}$	1.81	2.08	1.54	1.80	1.22	1.28
	SEM	.15	.13	.11	.12	.15	.12
LVG	11	2.32	2.21	2.22	1.76	2.03	1.51
	12	1.50	1.23	1.29	1.16	.80	.68
	13	1.78	2.64	1.25	1.48	1.30	1.22
	14	1.83	1.78	1.42	1.18	.95	.94
	15	1.84	2.23	1.57	1.03	1.52	.98
	16	1.96	2.46	1.68	1.52	1.75	1.54
	17	1.92	2.44	1.66	1.66	1.25	1.43
	18	1.87	2.30	1.26	1.74	1.14	1.32
	19	1.61	2.24	1.47	1.54	1.37	.98
	20	1.76	1.86	1.15	1.15	.90	.95
	$\bar{x}$	1.84	2.14	1.50	1.42	1.30	1.15
	SEM	.07	.13	.10	.09	.12	.09
CONG	21	1.61	1.60	1.37	1.29	1.11	.97
	22	1.86	2.33	1.89	1.45	1.51	1.50
	23	1.15	1.03	1.06	.91	.84	.87
	24	.55	.57	.27	.31	.21	.08
	25	1.51	1.47	1.64	1.57	1.59	1.33
	26	1.30	1.51	1.09	1.35	.88	.92
	27	1.20	.98	1.21	1.13	.95	.91
	28	1.73	1.35	1.43	.70	1.15	.94
	29	1.13	1.13	.49	.75	.44	.90
	30	1.15	.88	1.09	.88	.45	.40
	$\bar{x}$	1.32	1.28	1.15	1.03	.91	.83
	SEM	.12	.15	.15	.12	.14	.13

TABLE 17. Cinematographically determined centre of mass data for the three groups.

		HTRCM (cm)		GFOR (N)		VELTO ($m \cdot s^{-1}$)	
Group	Subject	Pre	Post	Pre	Post	Pre	Post
HVG	1	53.46	52.12	1199.34	1568.05	3.00	2.77
	2	44.43	46.06	1504.02	1246.01	2.70	2.68
	3	45.71	45.60	1149.62	1776.34	2.62	2.61
	4	49.64	49.61	1236.53	1024.43	2.93	2.81
	5	47.28	46.69	1056.91	1026.41	2.95	2.88
	6	45.75	47.94	1483.68	1292.72	2.71	2.71
	7	44.63	43.99	1165.05	1098.50	2.60	2.58
	8	50.90	56.64	1399.58	1519.33	3.01	3.09
	9	54.97	52.84	1347.71	1320.26	2.98	2.97
	10	48.61	47.54	921.12	994.02	2.90	2.68
	x̄	48.54	48.90	1246.36	1286.61	2.84	2.78
	SEM	1.16	1.23	59.29	83.90	.05	.05
LVG	11	50.55	47.40	1552.77	1359.58	2.87	2.83
	12	50.33	50.73	790.34	966.50	2.86	2.89
	13	41.27	39.46	1142.55	1209.04	2.51	2.40
	14	46.06	50.08	1075.64	1101.38	2.76	2.87
	15	50.04	53.19	1495.88	1711.17	2.76	2.73
	16	56.90	53.35	1334.60	1382.68	3.15	3.06
	17	45.28	46.14	853.50	999.99	2.63	2.70
	18	45.14	41.73	1005.66	1015.12	2.63	2.48
	19	44.82	44.75	839.77	904.95	2.56	2.62
	20	52.97	48.47	1351.52	1067.63	2.85	2.75
	x̄	48.34	47.53	1144.22	1171.80	2.76	2.73
	SEM	1.47	1.46	87.95	78.55	.06	.06
CONG	21	46.20	49.08	903.50	1467.69	2.86	2.87
	22	52.81	51.87	1404.72	1592.70	3.05	2.85
	23	44.07	47.19	1172.29	1174.03	2.46	2.73
	24	46.40	46.83	1316.06	1647.72	2.65	2.67
	25	50.75	50.31	900.44	752.76	2.86	2.69
	26	49.83	50.13	1176.98	986.49	2.89	2.93
	27	37.44	40.25	1180.68	1332.65	2.47	2.47
	28	51.11	49.26	950.82	1317.50	2.85	2.81
	29	44.70	46.00	1562.74	1547.92	2.86	2.75
	30	59.94	57.33	1373.23	1382.73	3.23	3.22
	x̄	48.32	48.82	1194.15	1320.22	2.82	2.80
	SEM	1.91	1.39	71.34	89.06	.05	.06

TABLE 17. Cinematographically determined centre of mass data for the three groups (continued).

Group	Number	GFOR (N) Pre	GFOR (N) Post
HVG	1	1199.34	1568.05
	2	1504.02	1246.01
	3	1149.62	1776.34
	4	1236.53	1024.43
	5	1056.91	1026.41
	6	1483.68	1292.72
	7	1165.05	1098.50
	8	1399.58	1519.33
	9	1347.71	1320.26
	10	921.12	994.02
	x̄	1246.36	1286.61
	SEM	59.29	83.90
LVG	11	1552.77	1359.58
	12	790.34	966.50
	13	1142.55	1209.04
	14	1075.64	1101.38
	15	1495.88	1711.17
	16	1334.60	1382.68
	17	853.50	999.99
	18	1005.66	1015.12
	19	839.77	904.95
	20	1351.52	1067.63
	x̄	1144.22	1171.80
	SEM	87.95	78.55
CONG	21	903.50	1467.69
	22	1404.72	1592.70
	23	1172.29	1174.03
	24	1316.06	1647.72
	25	900.44	752.76
	26	1176.98	986.49
	27	1180.68	1332.65
	28	950.82	1317.50
	29	1562.74	1547.92
	30	1373.23	1382.73
	x̄	1194.15	1320.22
	SEM	71.34	89.06

TABLE 18. Minimum angles for the hip, knee and ankle for the three groups on the vertical block jump (in rad).

Group	Subject	MAH Pre	MAH Post	MAK Pre	MAK Post	MAA Pre	MAA Post
HVG	1	1.48	1.75	1.24	1.55	1.56	1.61
	2	1.74	1.64	1.53	1.63	1.55	1.57
	3	1.83	2.07	1.47	1.75	1.30	1.36
	4	1.43	1.46	1.44	1.49	1.42	1.47
	5	1.21	1.29	1.34	1.42	1.39	1.48
	6	1.63	1.51	1.39	1.19	1.75	1.70
	7	1.83	1.60	1.61	1.55	1.45	1.54
	8	1.30	1.13	.98	.99	1.48	1.44
	9	1.26	1.18	1.29	1.28	1.27	1.33
	10	.94	1.12	1.53	1.44	1.44	1.48
	$\bar{x}$	1.47	1.47	1.38	1.43	1.46	1.50
	SEM	.09	.10	.06	.07	.04	.04
LVG	11	1.46	1.61	1.47	1.48	1.30	1.34
	12	1.31	1.38	1.27	1.24	1.31	1.19
	13	1.77	1.83	1.49	1.57	1.34	1.35
	14	1.40	1.40	1.35	1.26	1.28	1.28
	15	1.13	1.45	1.41	1.45	1.41	1.46
	16	1.42	1.47	1.41	1.40	1.39	1.37
	17	1.20	1.33	1.40	1.30	1.43	1.39
	18	1.30	1.29	1.06	1.03	1.60	1.59
	19	1.27	1.34	.84	.91	1.64	1.53
	20	1.54	1.47	1.24	1.38	1.38	1.36
	$\bar{x}$	1.38	1.46	1.29	1.30	1.41	1.38
	SEM	.06	.05	.06	.07	.04	.04
CONG	21	1.35	1.57	1.14	1.48	1.57	1.59
	22	1.54	1.56	1.54	1.55	1.39	1.45
	23	1.59	1.50	1.30	1.29	1.39	1.36
	24	1.63	1.65	1.51	1.52	1.44	1.47
	25	1.08	1.22	1.16	1.16	1.45	1.29
	26	1.46	1.43	1.41	1.38	1.36	1.42
	27	1.61	1.83	1.37	1.48	1.33	1.34
	28	1.36	1.71	1.31	1.44	1.43	1.48
	29	1.85	1.77	1.44	1.47	1.41	1.39
	30	1.21	1.09	1.32	1.28	1.33	1.33
	$\bar{x}$	1.47	1.53	1.35	1.40	1.41	1.41
	SEM	.07	.07	.04	.04	.02	.03

TABLE 19. Mean angular velocities for the hip, knee and ankle joints for the three groups on the vertical block jump (in rad·s^{-1}).

		MAVH		MAVK		MAVA	
Group	Subject	Pre	Post	Pre	Post	Pre	Post
HVG	1	4.08	4.21	5.27	6.31	2.49	3.15
	2	4.88	4.22	6.43	5.60	5.34	4.42
	3	4.54	3.80	6.88	7.29	5.51	6.51
	4	4.00	4.56	5.25	5.30	4.94	3.55
	5	4.83	5.08	5.93	5.54	3.70	4.76
	6	5.04	4.38	6.14	5.87	3.25	2.25
	7	4.37	3.86	8.05	5.60	6.72	4.07
	8	5.90	5.44	7.35	6.46	3.85	3.99
	9	4.96	4.70	5.85	5.18	5.35	3.77
	10	5.41	4.58	4.35	5.44	5.01	4.07
	X̄	4.80	4.48	6.15	5.86	4.62	4.05
	SEM	.18	.16	.34	.21	.40	.35
LVG	11	5.25	5.37	6.13	6.58	5.36	5.12
	12	4.88	5.22	4.98	6.05	3.72	4.26
	13	4.81	4.71	6.53	5.94	4.66	5.99
	14	5.21	5.29	6.13	6.60	3.64	3.94
	15	5.87	6.39	6.54	6.70	4.74	5.46
	16	5.08	5.06	6.25	5.72	5.45	4.84
	17	4.70	4.71	4.37	5.36	3.84	3.62
	18	4.69	4.59	5.37	5.19	1.97	2.69
	19	4.05	4.56	5.29	5.68	2.14	2.97
	20	4.62	4.61	6.35	5.98	4.11	3.51
	X̄	4.92	5.05	5.79	5.93	3.96	4.24
	SEM	.15	.18	.23	.15	.38	.35
CONG	21	4.15	4.51	5.27	6.04	4.32	4.09
	22	5.16	4.53	8.08	8.17	6.[illegible]3	5.28
	23	4.29	4.55	5.26	5.59	4.3[illegible]	4.04
	24	4.93	5.23	6.12	6.30	2.69	4.20
	25	4.47	4.85	5.57	5.50	4.45	5.18
	26	4.60	4.17	5.72	5.45	4.95	3.22
	27	4.32	4.62	5.37	5.63	4.86	4.00
	28	4.69	4.96	5.50	6.27	3.59	4.28
	29	4.80	5.52	7.26	6.42	4.97	4.81
	30	5.10	5.10	6.90	6.14	5.98	4.06
	X̄	4.65	4.80	6.10	6.15	4.63	4.32
	SEM	.11	.13	.31	.25	.32	.19

TABLE 20. Mean angular velocity times for the hip, knee and ankle joints for the three groups on the vertical block jump (in sec).

		MAVTH		MAVTK		MAVTA	
Group	Subject	Pre	Post	Pre	Post	Pre	Post
HVG	1	.30	.24	.27	.18	.33	.27
	2	.21	.24	.18	.18	.15	.15
	3	.24	.21	.21	.15	.21	.15
	4	.30	.30	.24	.24	.21	.27
	5	.30	.27	.24	.24	.24	.18
	6	.24	.30	.21	.24	.24	.33
	7	.27	.27	.15	.21	.15	.21
	8	.27	.30	.24	.27	.24	.24
	9	.33	.36	.27	.30	.21	.27
	10	.33	.33	.30	.24	.18	.21
	$\bar{X}$	.28	.28	.23	.22	.22	.23
	SEM	.01	.01	.01	.01	.02	.02
LVG	11	.24	.24	.21	.21	.21	.21
	12	.30	.27	.30	.27	.27	.27
	13	.24	.27	.21	.24	.21	.18
	14	.30	.30	.27	.27	.30	.27
	15	.27	.24	.21	.21	.21	.18
	16	.27	.27	.21	.24	.18	.21
	17	.33	.30	.27	.24	.24	.24
	18	.33	.33	.30	.30	.42	.30
	19	.36	.33	.36	.33	.39	.33
	20	.27	.30	.24	.24	.24	.27
	$\bar{X}$	.29	.28	.26	.25	.27	.25
	SEM	.01	.01	.02	.01	.03	.02
CONG	21	.33	.24	.30	.21	.21	.21
	22	.24	.24	.15	.15	.15	.18
	23	.30	.30	.27	.27	.24	.27
	24	.27	.24	.21	.21	.30	.21
	25	.36	.33	.30	.30	.21	.21
	26	.27	.30	.24	.24	.24	.33
	27	.30	.24	.27	.24	.21	.24
	28	.30	.24	.27	.21	.30	.21
	29	.24	.21	.18	.21	.18	.18
	30	.30	.33	.21	.24	.18	.24
	$\bar{X}$	.29	.27	.24	.23	.22	.23
	SEM	.01	.01	.02	.01	.02	.01

TABLE 21. Maximal angular velocities for the hip, knee and ankle joints for the three groups on the vertical block jump (in rad·s^{-1}).

		VMXH		VMXK		VMXA	
Group	Subject	Pre	Post	Pre	Post	Pre	Post
HVG	1	7.20	7.23	10.66	10.23	7.66	7.66
	2	8.56	9.17	11.23	9.87	8.83	6.86
	3	8.15	6.65	11.55	10.90	11.20	10.51
	4	7.60	9.32	10.99	12.25	9.68	10.56
	5	10.21	9.93	12.59	11.80	8.86	8.55
	6	8.94	9.94	11.25	12.00	7.03	6.72
	7	9.03	7.44	12.08	10.66	10.96	7.97
	8	10.21	11.19	13.98	14.18	9.87	9.15
	9	9.76	10.33	12.46	12.08	9.87	7.80
	10	9.78	8.84	11.91	11.35	8.50	8.02
	x̄	8.94	9.00	11.87	11.53	9.25	8.38
	SEM	.34	.47	.31	.39	.42	.42
LVG	11	10.34	9.98	12.26	13.19	9.72	9.03
	12	8.50	9.53	11.29	12.30	9.25	11.00
	13	9.26	8.21	12.86	11.83	10.34	10.51
	14	10.68	10.26	13.83	13.11	10.14	9.60
	15	10.20	10.83	11.48	12.97	9.45	9.40
	16	9.08	9.21	11.27	11.68	9.52	9.40
	17	8.38	9.37	10.36	10.91	8.89	9.47
	18	9.85	9.70	11.49	11.42	8.17	7.13
	19	8.89	9.03	11.79	12.57	7.11	9.57
	20	10.68	8.83	12.81	11.20	8.96	8.60
	x̄	9.58	9.49	11.94	12.12	9.15	9.37
	SEM	.28	.24	.32	.26	.30	.33
CONG	21	8.87	9.28	10.87	11.19	8.68	8.28
	22	10.50	9.17	13.05	12.63	10.36	9.84
	23	8.44	8.92	11.03	11.59	9.05	8.83
	24	9.62	9.99	11.76	12.80	9.04	8.20
	25	9.40	9.30	12.51	12.15	9.15	8.63
	26	8.15	6.85	10.75	10.73	8.85	9.76
	27	9.70	8.20	11.74	11.98	8.88	8.21
	28	9.61	10.63	12.05	12.58	10.05	8.48
	29	8.12	9.78	12.22	12.60	9.24	9.04
	30	8.53	9.55	11.68	11.84	10.04	9.79
	x̄	9.09	9.17	11.76	12.01	9.33	8.91
	SEM	.25	.33	.23	.22	.19	.21

TABLE 22. Impulse data for the three groups on the vertical block jump.

		FNI (N·s)		FNIT (s)		PI (N·s)		PIT (s)	
Group	Subject	Pre	Post	Pre	Post	Pre	Post	Pre	Post
HVG	1	89.46	62.92	.36	.21	157.90	289.85	.51	.32
	2	60.23	74.56	.23	.24	214.92	218.06	.31	.32
	3	40.90	42.24	.39	.21	181.77	214.05	.31	.24
	4	91.56	73.24	.39	.35	218.48	224.39	.41	.42
	5	93.01	66.15	.34	.30	217.97	174.65	.42	.49
	6	81.18	95.77	.29	.29	226.31	249.18	.34	.40
	7	63.94	52.14	.21	.26	189.52	194.53	.27	.31
	8	69.15	48.59	.52	.51	238.52	283.22	.36	.37
	9	115.29	132.07	.36	.32	273.08	270.55	.48	.50
	10	60.41	64.35	.38	.41	187.48	212.61	.48	.44
	$\bar{x}$	76.51	71.20	.35	.31	210.59	233.11	.39	.38
	SEM	6.83	8.29	.03	.03	10.36	12.19	.03	.03
LVG	11	67.83	64.63	.30	.27	249.12	198.56	.34	.32
	12	68.21	73.88	.32	.36	195.15	231.59	.51	.45
	13	63.40	70.01	.36	.27	198.26	194.30	.34	.35
	14	82.51	91.34	.43	.36	200.82	260.55	.43	.44
	15	85.12	81.44	.38	.31	263.74	247.85	.37	.32
	16	72.14	86.61	.31	.33	266.30	236.85	.37	.37
	17	13.49	41.68	.59	.54	184.93	185.72	.44	.37
	18	96.55	89.40	.41	.37	241.85	225.65	.46	.49
	19	79.52	79.19	.45	.43	218.33	186.97	.59	.49
	20	88.70	65.79	.41	.39	21[illegible].28	177.38	.39	.46
	$\bar{x}$	71.75	74.40	.40	.36	223.48	214.54	.42	.41
	SEM	7.26	4.71	.03	.03	9.41	9.29	.03	.02
CONG	21	119.63	84.87	.37	.36	249.10	223.24	.53	.34
	22	76.07	71.90	.25	.25	211.94	225.74	.30	.29
	23	76.53	93.21	.34	.44	219.77	253.17	.40	.42
	24	74.24	71.24	.29	.23	257.74	334.06	.35	.32
	25	75.59	62.62	.38	.36	186.08	143.31	.49	.52
	26	76.72	95.82	.31	.32	253.87	195.31	.40	.41
	27	46.33	58.56	.60	.50	172.44	238.00	.44	.32
	28	82.40	71.00	.32	.27	207.19	237.86	.46	.33
	29	71.68	71.78	.26	.26	243.27	246.99	.31	.33
	30	104.25	86.60	.34	.39	275.87	282.90	.42	.44
	$\bar{x}$	80.34	76.76	.35	.34	227.73	238.06	.41	.37
	SEM	6.20	4.00	.03	.03	10.61	15.89	.02	.02

TABLE 22. Impulse data for the three groups on the vertical block jump (continued).

		SNI (N·s)		SNIT (s)		TPI (N·s)		TPIT (s)	
Group	Subject	Pre	Post	Pre	Post	Pre	Post	Pre	Post
HVG	1	17.19	9.89	.03	.02	161.21	189.97	.90	.55
	2	10.58	9.45	.02	.02	186.19	175.55	.56	.58
	3	13.37	9.39	.03	.02	167.46	146.31	.73	.47
	4	16.80	17.72	.03	.03	187.78	233.28	.83	.80
	5	12.49	14.04	.03	.03	165.26	203.90	.79	.82
	6	20.97	19.54	.03	.03	182.69	185.56	.66	.72
	7	10.48	7.88	.03	.02	137.10	134.05	.51	.59
	8	8.04	13.37	.02	.03	177.08	202.77	.90	.91
	9	16.55	10.62	.03	.02	231.82	200.41	.87	.84
	10	8.20	14.15	.02	.03	161.19	169.18	.88	.88
	$\bar{X}$	13.47	12.60	.03	.02	175.78	184.10	.76	.72
	SEM	1.36	1.22	.00	.00	7.85	9.24	.05	.05
LVG	11	7.94	8.57	.02	.02	160.55	163.24	.66	.61
	12	9.85	11.14	.03	.03	143.65	193.12	.86	.84
	13	14.14	18.27	.03	.03	166.65	178.09	.73	.65
	14	17.85	12.96	.03	.02	169.41	180.37	.89	.82
	15	18.15	19.42	.03	.03	203.73	204.73	.78	.66
	16	11.50	17.73	.03	.03	188.90	203.12	.71	.73
	17	14.35	10.61	.03	.03	127.47	139.24	1.06	.94
	18	10.22	13.29	.01	.03	212.07	150.11	.88	.89
	19	11.83	16.70	.02	.03	283.41	163.85	1.06	.95
	20	18.45	18.74	.03	.03	195.66	200.23	.83	.88
	$\bar{X}$	13.43	14.74	.03	.03	185.15	177.61	.85	.80
	SEM	1.19	1.23	.00	.00	13.78	7.28	.04	.04
CONG	21	12.06	18.42	.02	.03	274.21	196.91	.92	.73
	22	9.65	9.68	.02	.02	166.57	164.91	.57	.56
	23	19.55	17.79	.04	.03	152.51	191.52	.78	.89
	24	13.65	14.43	.03	.03	164.45	215.64	.67	.58
	25	12.61	8.45	.03	.02	153.31	153.27	.90	.90
	26	11.82	8.94	.03	.02	170.26	134.70	.74	.75
	27	12.28	16.81	.02	.03	212.87	199.25	1.06	.85
	28	12.42	11.20	.03	.03	156.13	173.00	.81	.63
	29	19.65	9.17	.03	.02	198.27	170.37	.60	.61
	30	8.92	12.90	.02	.03	180.45	195.23	.78	.86
	$\bar{X}$	13.26	12.78	.03	.03	182.90	179.48	.78	.74
	SEM	1.15	1.22	.00	.00	11.91	7.76	.05	.04

TABLE 23. Ground reaction force data for the three groups on the vertical block jump.

Group	Subject	FMIN(N)		FMAX(N)		TFMIN(s)		TFMAX(s)	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
HVG	1	383.13	28.11	1533.69	2084.01	.78	.40	.31	.18
	2	105.90	59.40	2044.27	1994.86	.39	.39	.14	.16
	3	425.09	671.18	1790.40	2233.76	.52	.43	.17	.15
	4	356.12	324.25	1798.35	1844.78	.55	.62	.22	.23
	5	260.81	325.37	1636.91	1673.72	.58	.66	.20	.20
	6	194.89	165.55	1970.26	1837.00	.42	.51	.23	.34
	7	70.35	146.29	1789.96	1614.19	.38	.43	.12	.14
	8	466.23	494.95	1922.88	2014.55	.48	.50	.24	.27
	9	367.75	236.02	1947.96	1907.06	.67	.66	.29	.29
	10	387.34	421.14	1446.10	1523.81	.61	.63	.16	.09
	x̄	301.76	287[illegible]	1788.08	1872.77	.56	.55	.21	.20
	SEM	43.27	63[illegible]	62.11	70.03	.01	.01	.02	.02
LVG	11	124.35	171.37	1895.67	1801.41	.48	.41	.24	.21
	12	176.39	124.38	1295.24	1444.83	.68	.59	.25	.27
	13	412.14	252.73	1741.92	1838.83	.48	.49	.20	.21
	14	480.21	332.40	1753.20	1738.75	.71	.63	.17	.25
	15	419.69	268.57	2159.84	2284.39	.54	.[illegible]6	.23	.19
	16	218.89	210.20	1784.70	1889.69	.50	.50	.20	.22
	17	616.88	416.48	1173.90	1476.53	.8[illegible]	.57	.06	.25
	18	307.48	308.75	1742.65	1628.28	.65	.69	.25	.32
	19	390.66	428.[illegible]	2306.98	1627.59	.72	.62	.07	.32
	20	485.05	580.[illegible]2	1994.30	1848.96	.56	.66	.19	.10
	x̄	363.17	309.42	1784.84	1757.93	.55	.54	.19	.23
	SEM	48.89	43.17	109.90	76.20	.01	.01	.02	.02
CONG	21	207.95	285.95	2021.92	1973.50	.68	.48	.2[illegible]	.22
	22	67.01	56.31	1963.11	1989.84	.39	.38	.15	.17
	23	443.73	438.93	1793.31	1848.18	.55	.60	.27	.27
	24	168.19	16.48	1899.37	2178.40	.47	.38	.11	.19
	25	289.13	364.80	1367.34	1353.65	.68	.74	.28	.29
	26	92.81	108.28	1717.60	1484.35	.52	.51	.24	.25
	27	808.95	703.51	1923.80	2296.02	.91	.48	.16	.16
	28	217.78	166.28	1415.02	1837.31	.66	.48	.07	[illegible]
	29	187.51	201.33	2084.35	2003.01	.40	.42	.2[illegible]	.17
	30	148.69	115.70	1796.83	1763.80	.54	.60	.28	.24
	x̄	263.17	245.76	1798.19	1872.81	.55	.56	.20	.21
	SEM	69.25	66.27	76.30	91.13	.01	.01	.02	.01

APPENDIX E

TABLE 24. Summary of the statistical analysis for subject age - Pre (AGEPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	23.0969	2	11.5484	1.25	0.301	N.S.
ERROR	248.5972	27	9.2073			

* Significantly different at $p \leq 0.05$.

TABLE 25. Summary of the statistical analysis for subject body mass - Pre (MASSPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	9.8847	2	4.9423	0.06	0.940	N.S.
ERROR	2163.0540	27	80.1131			

* Significantly different at $p \leq 0.0$[illegible]

TABLE 26. Summary of the statistical analysis for pre to post difference in subject body mass (DIFFMASS).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.6847	2	0.3423	0.25	0.782	N.S.
ERROR	37.2850	27	1.3809			

* Significantly different at $p \leq 0.05$.

TABLE 27. Summary of the statistical analysis for subject lean body mass - Pre (LBMPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	4.2812	2	2.1406	0.05	0.952	N.S.
ERROR	1160.0835	27	42.9661			

* Significantly different at $p \leq 0.05$.

TABLE 28. Summary of the statistical analysis for pre to post difference in subject lean body mass (DIFFLBM).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	2.6568	2	1.3284	1.05	0.362	N.S.
ERROR	34.0064	27	1.2595			

* Significantly different at p≤0.05.

TABLE 29. Summary of the statistical analysis for subject percent fat - Pre (PBFPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	24.0766	2	12.0383	.58	0.566	N.S.
ERROR	558.9555	27	20.7021			

* Significantly different at p≤0.05.

TABLE 30. Summary of the statistical analysis for pre to post difference in subject percent body fat (DIFFPBF).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	2.4026	2	1.2013	0.63	0.540	N.S.
ERROR	51.4980	27	1.9073			

* Significantly different at $p \leq 0.05$.

TABLE 31. Summary of the statistical analysis for relative peak torque of the knee at 0.0 $rad \cdot s^{-1}$ - Pre (KRPTOPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.1409	2	0.0705	0.38	0.689	N.S.
ERROR	5.0440	27	0.1868			

* Significantly different at $p \leq 0.05$.

TABLE 32. Summary of the statistical analysis for relative peak torque of the knee at 0.5 rad·s^{-1} - Pre (KRPT0.5PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.3391	2	0.1696	1.24	0.306	N.S.
ERROR	3.7017	27	0.1371			

* Significantly different at $p \leq 0.05$.

TABLE 33. Summary of the statistical analysis for relative peak torque of the knee at 1.0 rad·s^{-1} - Pre (KRPT1PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.1992	2	0.0996	1.11	0.344	N.S.
ERROR	2.4213	27	0.0897			

* Significantly different at $p \leq 0.05$.

TABLE 34. Summary of the statistical analysis for relative peak torque of the knee at 2.0 rad·s^{-1} - Pre (KRPT2PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.2017	2	0.1008	2.04	0.150	N.S.
ERROR	1.3367	27	0.0495			

* Significantly different at $p \leq 0.05$.

TABLE 35. Summary of the statistical analysis for relative peak torque of the knee at 3.0 rad·s^{-1} - Pre (KRPT3PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0418	2	0.0209	0.79	0.462	N.S.
ERROR	0.7101	27	0.0253			

* Significantly different at $p \leq 0.05$.

TABLE 36. Summary of the statistical analysis for relative peak torque of the knee at 4.0 rad·s^{-1} - Pre (KRPT4PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0042	2	0.0021	0.10	[illegible]09	N.S.
ERROR	0.5975	27	0.0221			

* Significantly different at $p \leq 0.05$.

TABLE 37. Summary of the statistical analysis for relative peak torque of the knee at 5.0 rad·s^{-1} - Pre (KRPT5PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0277	2	0.0139	0.71	0.502	N.S.
ERROR	0.5291	27	0.0196			

* Significantly different at $p \leq 0.05$.

TABLE 38. Summary of the statistical analysis for pre to post difference in relative peak torque of the knee at 0.0 rad·s^{-1} (DIFFKRPTO).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	1.6839	2	0.8419	9.80	0.001	Sig.
ERROR	2.3193	27	0.0959			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
LVG	0.480	A	
HVG	0.119	B B	0.339
CONG	-0.094	B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 39. Summary of the statistical analysis for pre to post difference in relative peak torque of the knee at 0.5 rad·s^{-1} (DIFFKRPT0.5).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	1.3261	2	0.6631	7.00	0.004	Sig.
ERROR	2.5577	27	0.0447			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*		Minimum Significant Difference
LVG	0.544	A		
		A		
HVG	0.281	A	B	0.357
			B	
CONG	0.029		B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 40. Summary of the statistical analysis for pre to post difference in relative peak torque of the knee at 1.0 rad·s^{-1} (DIFFKRPT1).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	1.6605	2	0.8302	15.55	0.000	Sig.
ERROR	1.4415	27	0.0534			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
LVG	0.577	A	
HVG	0.189	B B	0.268
CONG	0.014	B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 41. Summary of the statistical analysis for pre to post difference in relative peak torque of the knee at 2.0 rad$\cdot$s^{-1} (DIFFKRPT2).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.1981	2	0.0990	5.43	0.010	Sig.
ERROR	0.4927	27	0.0182			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*		Minimum Significant Difference
LVG	0.215	A		
		A		
HVG	0.112	A	B	0.156
			B	
CONG	0.016		B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 42. Summary of the statistical analysis for pre to post difference in relative peak torque of the knee at 3.0 rad·s^{-1} (DIFFKRPT3).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.2104	2	0.1052	9.60	0.001	Sig.
ERROR	0.2959	27	0.0110			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
LVG	0.243	A	
		A	
HVG	0.173	A	0.121
CONG	0.041	B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 43. Summary of the statistical analysis for pre to post difference in relative peak torque of the knee at 4.0 rad·s^{-1} (DIFFKRPT4).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.4874	2	0.2437	19.00	0.000	Sig.
ERROR	0.3463	27	0.0128			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
HVG	0.236	A	0.131
		A	
LVG	0.174	A	
CONG	-0.060	B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 44. Summary of the statistical analysis for pre to post difference in relative peak torque of the knee at 5.0 rad·s^{-1} (DIFFKRPT5).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.3608	2	0.1804	17.63	0.000	Sig.
ERROR	0.2763	27	0.0102			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
HVG	0.261	A	
LVG	0.143	B	0.117
CONG	-0.007	C	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 45. Summary of the statistical analysis for relative peak torque of the ankle at 0.0 rad·s^{-1} - Pre (ARPTOPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.2042	2	0.1021	1.09	0.351	N.S.
ERROR	2.5325	27	0.0938			

* Significantly different at $p \leq 0.05$.

TABLE 46. Summary of the statistical analysis for relative peak torque of the ankle at 0.5 rad·s^{-1} - Pre (ARPT0.5PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0488	2	0.0244	0.25	0.783	N.S.
ERROR	2.6706	27	0.0989			

* Significantly different at $p \leq 0.05$.

TABLE 47. Summary of the statistical analysis for relative peak torque of the ankle at 1.0 rad·s^{-1} - Pre (ARPT1PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0414	2	0.0207	0.41	0.670	N.S.
ERROR	1.3737	27	0.0509			

* Significantly different at $p \leq 0.05$.

TABLE 48. Summary of the statistical analysis for relative peak torque of the ankle at 2.0 rad·s^{-1} - Pre (ARPT2PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.1525	2	0.0762	3.07	0.063	N.S.
ERROR	0.6698	27	0.0280			

* Significantly different at $p \leq 0.05$.

TABLE 49. Summary of the statistical analysis for relative peak torque of the ankle at 3.0 rad·s^{-1} - Pre (ARPT3PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.1879	2	0.0939	6.33	0.006	Sig.
ERROR	0.4008	27	0.0148			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
LVG	0.606	A A	
HVG	0.593	A	0.141
CONG	0.432	B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 50. Summary of the statistical analysis for relative peak torque of the ankle at 4.0 rad·s^{-1} - Pre (ARPT4PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0557	2	0.0279	2.93	0.071	N.S.
ERROR	0.2570	27	0.0095			

* Significantly different at $p \leq 0.05$.

TABLE 51. Summary of the statistical analysis for relative peak torque of the ankle of 5.0 rad·s^{-1} - Pre (ARPT5PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0375	2	0.0188	2.38	0.112	N.S.
ERROR	0.2130	27	0.0079			

* Significantly different at $p \leq 0.05$.

TABLE 52. Summary of the statistical analysis for pre to post difference in relative peak torque of the ankle at 0.0 rad·s^{-1} (DIFFARPTO).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.2278	2	0.1139	2.32	0.118	N.S.
ERROR	1.3268	27	0.0491			

* Significantly different at $p \leq 0.05$.

TABLE 53. Summary of the statistical analysis for pre to post difference in relative peak torque of the ankle at 0.5 rad·s^{-1} (DIFFARPTO.5).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.2408	2	0.1204	3.74	0.037	Sig.
ERROR	0.8695	27	0.0322			

* Significantly different at $p \leq 0.05$.

TABLE 53. Summary of the statistical analysis for pre to post difference in relative peak torque of the ankle at 0.5 rad·s^{-1} (DIFFARPT0.5) (continued).

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*		Minimum Significant Difference
LVG	0.291	A		
		A		
HVG	0.169	A	B	0.208
			B	
CONG	0.072		B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 54. Summary of the statistical analysis for pre to post difference in relative peak torque of the ankle at 1.0 rad·s^{-1} (DIFFARPT1)

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.3104	2	0.1552	9.93	0.001	Sig.
ERROR	0.4221	27	0.0156			

* Significantly different at $p \leq 0.05$.

TABLE 54. Summary of the statistical analysis for pre to post difference in relative peak torque of the ankle at 1.0 rad·s^{-1} (DIFFARPT1) (continued).

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*		Minimum Significant Difference
LVG	0.284	A		
		A		
HVG	0.167	A	B	0.145
			B	
CONG	0.035		B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 55. Summary of the statistical analysis for pre to post difference in relative peak torque of the ankle at 2.0 rad·s^{-1} (DIFFARPT2).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0454	2	0.0227	1.88	0.172	N.S.
ERROR	0.3260	27	0.0121			

* Significantly different at $p \leq 0.05$.

TABLE 56. Summary of the statistical analysis for pre to post difference in relative peak torque of the ankle at 3.0 rad·s^{-1} (DIFFARPT3).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0724	2	0.0362	2.35	0.115	N.S.
ERROR	0.4159	27	0.0154			

* Significantly different at $p \leq 0.05$.

TABLE 57. Summary of the statistical analysis for pre to post difference in relative peak torque of the ankle at 4.0 rad·s^{-1} (DIFFARPT4).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0559	2	0.0280	4.08	0.028	Sig.
ERROR	0.1851	27	0.0069			

* Significantly different at $p \leq 0.05$.

TABLE 57. Summary of the statistical analysis for pre to post difference in relative peak torque of the ankle at 4.0 rad·s^{-1} (DIFFARPT4) (continued).

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
HVG	0.063	A	
		A	
LVG	-0.026	A	0.096
		A	
CONG	-0.031	A	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 58. Summary of the statistical analysis for pre to post difference in relative peak torque of the ankle at 5.0 rad·s^{-1} (DIFFARPT5).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0089	2	0.0045	1.64	0.212	N.S.
ERROR	0.0734	27	0.0027			

* Significantly different at $p \leq 0.05$.

TABLE 59. Summary of the statistical analysis for relative peak power of the knee at 0.5 rad·s^{-1} - Pre (KRPP0.5PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.1219	2	0.0610	1.21	0.313	N.S.
ERROR	1.3585	27	0.0503			

* Significantly different at $p \leq 0.05$.

TABLE 60. Summary of the statistical analysis for relative peak power of the knee at 1.0 rad·s^{-1} - Pre (KRPP1PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.1408	2	0.0704	0.65	0.531	N.S.
ERROR	2.9284	27	0.1085			

* Significantly different at $p \leq 0.05$.

TABLE 61. Summary of the statistical analysis for relative peak power of the knee at 2.0 rad·s^{-1} - Pre (KRPP2PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.6066	2	0.3033	1.47	0.248	N.S.
ERROR	5.5808	27	0.2067			

* Significantly different at $p \leq 0.05$.

TABLE 62. Summary of the statistical analysis for relative peak power of the knee at 3.0 rad·s^{-1} - Pre (KRPP3PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.3979	2	0.1989	0.81	0.455	N.S.
ERROR	6.6232	27	0.2453			

* Significantly different at $p \leq 0.05$.

TABLE 63. Summary of the statistical analysis for relative peak power of the knee at 4.0 rad·s^{-1} - Pre (KRPP4PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0996	2	0.0498	0.13	0.877	N.S.
ERROR	10.2064	27	0.3780			

* Significantly different at $p \leq 0.05$.

TABLE 64. Summary of the statistical analysis for relative peak power of the knee at 5.0 rad·s^{-1} - Pre (KRPP5PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.6097	2	0.3048	0.62	0.546	N.S.
ERROR	13.2895	27	0.4922			

* Significantly different at $p \leq 0.05$.

TABLE 65. Summary of the statistical analysis for pre to post difference in relative peak power of the knee at 0.5 rad·s^{-1} (DIFFKRPP0.5).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.6125	2	0.3063	8.05	0.002	Sig.
ERROR	1.0268	27	0.0380			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*		Minimum Significant Difference
LVG	0.374	A		
		A		
HVG	0.198	A	B	0.226
			B	
CONG	0.024		B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 66. Summary of the statistical analysis for pre to post difference in relative peak power of the knee at 1.0 rad·s^{-1} (DIFFKRPP1).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	2.2223	2	1.111	17.80	0.000	Sig.
ERROR	1.6857	27	0.0624			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
LVG	0.681	A	
HVG	0.207	B	0.289
		B	
CONG	0.038	B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 67. Summary of the statistical analysis for pre to post difference in relative peak power of the knee at 2.0 rad$\cdot$s^{-1} (DIFFKRPP2).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	1.4308	2	0.7154	7.77	0.002	Sig.
ERROR	2.4866	27	0.0921			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*		Minimum Significant Difference
LVG	0.520	A		
		A		
HVG	0.293	A	B	0.352
			B	
CONG	-0.013		B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 68. Summary of the statistical analysis for pre to post difference in relative peak power of the knee at 3.0 rad·s^{-1} (DIFFKRPP3).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	35349.4119	2	17674.7059	5.69	0.009	Sig.
ERROR	83913.9272	27	3107.9232			

* Significantly different at p≤0.05.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*		Minimum Significant Difference
LVG	729.73	A		
		A		
HVG	672.31	A	B	64.574
			B	
CONG	647.83		B	

* Means with the same letter are not significantly different at p≤0.05.

TABLE 69. Summary of the statistical analysis for pre to post difference in relative peak power of the knee at 4.0 rad·s^{-1} (DIFFKRPP4).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	8.0785	2	4.0393	19.90	0.000	Sig.
ERROR	5.4805	27	0.2030			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
HVG	0.975	A	
		A	
LVG	0.704	A	0.522
CONG	-0.236	B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 70. Summary of the statistical analysis for pre to post difference in relative peak power of the knee at 5.0 rad·s^{-1} (DIFFKRPP5).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	9.0070	2	4.5035	15.80	0.000	Sig.
ERROR	7.6973	27	0.2851			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
HVG	1.317	A	
LVG	0.664	B	0.618
CONG	-0.025	C	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 71. Summary of the statistical analysis for relative peak power of the ankle at 0.5 rad·s^{-1} - Pre (ARPP0.5PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0168	2	0.0084	0.30	0.745	N.S.
ERROR	0.7631	27	0.0283			

* Significantly different at $p \leq 0.05$.

TABLE 72. Summary of the statistical analysis for relative peak power of the ankle at 1.0 rad·s^{-1} - Pre (ARPP1PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0462	2	0.0231	0.41	0.668	N.S.
ERROR	1.5208	27	0.0563			

* Significantly different at $p \leq 0.05$.

TABLE 73. Summary of the statistical analysis for relative peak power of the ankle at 2.0 rad·s^{-1} - Pre (ARPP2PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.6292	2	0.3146	3.00	0.070	N.S.
ERROR	2.8357	27	0.1050			

* Significantly different at $p \leq 0.05$.

TABLE 74. Summary of the statistical analysis for relative peak power of the ankle at 3.0 rad·s^{-1} - Pre (ARPP3PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	1.7202	2	0.8601	6.08	0.007	Sig.
ERROR	3.8184	27	0.1414			

* Significantly different at $p \leq 0.05$.

TABLE 74. Summary of the statistical analysis for relative peak power of the ankle at 3.0 $rad \cdot s^{-1}$ - Pre (ARPP3PRE) (continued).

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
LVG	1.839	A	
		A	
HVG	1.814	A	0.436
CONG	1.319	B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 75. Summary of the statistical analysis for relative peak power of the ankle at 4.0 $rad \cdot s^{-1}$ - Pre (ARPP4PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.9007	2	0.4504	2.89	0.073	N.S.
ERROR	4.2034	27	0.1557			

* Significantly different at $p \leq 0.05$.

TABLE 76. Summary of the statistical analysis for relative peak power of the ankle at 5.0 rad·s^{-1} - Pre (ARPP5PRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.8409	2	0.4204	2.13	0.139	N.S.
ERROR	5.3331	27	0.1975			

* Significantly different at $p \leq 0.05$.

TABLE 77. Summary of the statistical analysis for pre to post difference in relative peak power of the ankle at 0.5 rad·s^{-1} (DIFFARPP0.5).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0642	2	0.0321	2.58	0.094	N.S.
ERROR	0.3357	27	0.0124			

* Significantly different at $p \leq 0.05$.

TABLE 78. Summary of the statistical analysis for pre to post difference in relative peak power of the ankle at 1.0 rad·s^{-1} (DIFFARPP1).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.3280	2	0.1640	9.05	0.001	Sig.
ERROR	0.4893	27	0.0181			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*		Minimum Significant Difference
LVG	0.308	A		
		A		
HVG	0.173	A	B	0.156
			B	
CONG	0.052		B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 79. Summary of the statistical analysis for pre to post difference in relative peak power of the ankle at 2.0 rad·s^{-1} (DIFFARPP2).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.2363	2	0.1181	2.21	0.130	N.S.
ERROR	1.4451	27	0.0535			

* Significantly different at $p \leq 0.05$.

TABLE 80. Summary of the statistical analysis for pre to post difference in relative peak power of the ankle at 3.0 rad·s^{-1} (DIFFARPP3).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.6739	2	0.3370	2.36	0.114	N.S.
ERROR	3.8607	27	0.1430			

* Significantly different at $p \leq 0.05$.

TABLE 81. Summary of the statistical analysis for pre to post difference in relative peak power of the ankle at 4.0 rad·s^{-1} (DIFFARPP4).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.8479	2	0.4240	3.68	0.039	Sig.
ERROR	3.1107	27	0.1152			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
HVG	0.257	A	
		A	
LVG	-0.075	A	0.393
		A	
CONG	-0.120	A	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 82. Summary of the statistical analysis for pre to post difference in relative peak power of the ankle at 5.0 rad·s^{-1} (DIFFARPP5).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.21172	2	0.1086	1.54	0.232	N.S.
ERROR	1.9023	27	0.0705			

* Significantly different at $p \leq 0.05$.

TABLE 83. Summary of the statistical analysis for height of rise of the centre of mass - Pre (HTRCMPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.2876	2	0.1438	0.01	0.994	N.S.
ERROR	644.3939	27	23.8664			

* Significantly different at $p \leq 0.05$.

TABLE 84. Summary of the statistical analysis for pre to post difference in height of rise of the centre of mass (DIFFHTRCM).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	10.3170	2	5.1585	0.86	0.435	N.S.
ERROR	162.1883	27	6.0070			

* Significantly different at $p \leq 0.05$.

TABLE 85. Summary of the statistical analysis for vertical velocity at take-off - Pre (VELTOPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0374	2	0.0187	0.47	0.631	N.S.
ERROR	1.0787	27	0.0400			

* Significantly different at $p \leq 0.05$.

TABLE 86. Summary of the statistical analysis for pre to post difference in vertical velocity at take-off (DIFFVELTO).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0113	2	0.0057	0.49	0.619	N.S.
ERROR	0.3131	27	0.0116			

* Significantly different at $p \leq 0.05$.

TABLE 87. Summary of the statistical analysis for ground force - Pre (GFORPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	52164.4657	2	26082.2329	0.48	0.625	N.S.
ERROR	1470583.6007	27	54466.0593			

* Significantly different at $p \leq 0.05$.

TABLE 88. Summary of the statistical analysis for pre to post difference in ground force (DIFFGFOR).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	57422.0622	2	28711.0311	0.54	0.587	N.S.
ERROR	1427854.3468	27	52883.4943			

* Significantly different at $p \leq 0.05$.

TABLE 89. Summary of the statistical analysis for minimum angle at the hip - Pre (MAHPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0492	2	0.0246	0.43	0.653	N.S.
ERROR	1.5309	27	0.0567			

* Significantly different at $p \leq 0.05$.

TABLE 90. Summary of the statistical analysis for mean angular velocity of the hip - Pre (MAVHPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.3584	2	0.1792	0.78	0.471	N.S.
ERROR	6.2413	27	0.2312			

* Significantly different at $p \leq 0.05$.

TABLE 91. Summary of the statistical analysis for mean angular velocity time of the hip - Pre (MAVTHPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0010	2	0.0005	0.31	0.735	N.S.
ERROR	0.0417	27	0.0015			

* Significantly different at $p \leq 0.05$.

TABLE 92. Summary of the statistical analysis for maximal angular velocity of the hip - Pre (VMXHPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	2.2524	2	1.1262	1.34	0.279	N.S.
ERROR	22.7076	27	0.8410			

* Significantly different at $p \leq 0.05$.

TABLE 93. Summary of the statistical analysis for pre to post difference in minimum angle at the hip (DIFFMAH).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0255	2	0.0128	0.57	0.573	N.S.
ERROR	0.6061	27	0.0224			

* Significantly different at $p \leq 0.05$.

TABLE 94. Summary of the statistical analysis for pre to post difference in mean angular velocity of the hip (DIFFMAVH).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	1.4008	2	0.7004	4.73	0.017	Sig.
ERROR	3.9987	27	0.1481			

* Significantly different at $p \leq 0.05$.

Scheffe Multiple Comparison of Means

Group	Mean	Scheffe Grouping*	Minimum Significant Difference
CONG	0.153	A	0.446
		A	
LVG	0.133	A	
HVG	-0.316	B	

* Means with the same letter are not significantly different at $p \leq 0.05$.

TABLE 95. Summary of the statistical analysis for pre to post difference in mean angular velocity time of the hip (DIFFMAVTH).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0038	2	0.0019	1.66	0.208	N.S.
ERROR	0.0307	27	0.0011			

* Significantly different at $p \leq 0.05$.

TABLE 96. Summary of the statistical analysis for pre to post difference in maximal angular velocity of the hip (DIFFVMXH).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.1651	2	0.0825	0.08	0.928	N.S.
ERROR	29.6478	27	1.0981			

* Significantly different at $p \leq 0.05$.

TABLE 97. Summary of the statistical analysis for minimum angle at the knee - Pre (MAKPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0383	2	0.0192	0.62	0.545	N.S.
ERROR	0.8332	27	0.0309			

* Significantly different at $p \leq 0.05$.

TABLE 98. Summary of the statistical analysis for mean angular velocity of the knee - Pre (MAVKPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.7495	2	0.3747	0.42	0.663	N.S.
ERROR	22.2247	27	0.8972			

* Significantly different at $p \leq 0.05$.

TABLE 99. Summary of the statistical analysis for mean angular velocity time of the knee - Pre (MAVTKPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0038	2	0.0019	0.78	0.468	N.S.
ERROR	0.0653	27	0.0024			

* Significantly different at $p \leq 0.05$.

TABLE 100. Summary of the statistical analysis for maximal angular velocity of the knee - Pre (VMXKPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.1593	2	0.0797	0.10	0.909	N.S.
ERROR	22.4320	27	0.8308			

* Significantly different at $p \leq 0.05$.

TABLE 101. Summary of the statistical analysis for pre to post difference in minimum angle at the knee (DIFFMAK).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0120	2	0.0060	0.41	0.671	N.S.
ERROR	0.3987	27	0.0148			

* Significantly different at $p \leq 0.05$.

TABLE 102. Summary of the statistical analysis for pre to post difference in mean angular velocity of the knee (DIFFMAVK).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.9992	2	0.4996	0.86	0.434	N.S.
ERROR	15.6726	27	0.5805			

* Significantly different at $p \leq 0.05$.

TABLE 103. Summary of the statistical analysis for pre to post difference in mean angular velocity time of the knee (DIFFMAVTK).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.004	2	0.0002	0.15	0.864	N.S.
ERROR	0.386	27	0.0014			

* Significantly different at $p \leq 0.05$.

TABLE 104. Summary of the statistical analysis for pre to post difference in maximal angular velocity of the knee (DIFFVMXK).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	2.0409	2	1.0204	1.59	0.222	N.S.
ERROR	17.3273	27	0.6418			

* Significantly different at $p \leq 0.05$.

TABLE 105. Summary of the statistical analysis for minimum angle at the ankle - Pre (MAAPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0194	2	0.0097	0.75	0.482	N.S.
ERROR	0.3484	27	0.0129			

* Significantly different at $p \leq 0.05$.

TABLE 106. Summary of the statistical analysis for mean angular velocity of the ankle - Pre (MAVAPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	2.9277	2	1.4639	1.08	0.353	N.S.
ERROR	36.4956	27	1.3517			

* Significantly different at $p \leq 0.05$.

TABLE 107. Summary of the statistical analysis for mean angular velocity time of the ankle - Pre (MAVTAPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0155	2	0.0078	1.99	0.156	N.S.
ERROR	0.1052	27	0.0039			

* Significantly different at $p \leq 0.05$.

TABLE 108. Summary of the statistical analysis for maximal angular velocity of the ankle - Pre (VMXAPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.1597	2	0.0798	0.08	0.924	N.S.
ERROR	27.3263	27	1.0121			

* Significantly different at $p \leq 0.05$.

TABLE 109. Summary of the statistical analysis for pre to post difference in minimum angle at the ankle (DIFFMAA).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0175	2	0.0088	2.78	0.080	N.S.
ERROR	0.0850	27	0.0031			

* Significantly different at $p \leq 0.05$.

TABLE 110. Summary of the statistical analysis for pre to post difference in mean angular velocity of the ankle (DIFFMAVA).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	3.7387	2	1.8693	1.79	0.186	N.S.
ERROR	28.1787	27	1.0437			

* Significantly different at $p \leq 0.05$.

TABLE 111. Summary of the statistical analysis for pre to post difference in mean angular velocity time of the ankle (DIFFMAVTA).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0062	2	0.0031	1.08	0.355	N.S.
ERROR	0.0775	27	0.0029			

* Significantly different at $p \leq 0.05$.

TABLE 112. Summary of the statistical analysis for pre to post difference in maximal angular velocity of the ankle (DIFFVMXA).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	5.9248	2	2.9624	3.05	0.064	N.S.
ERROR	26.2065	27	0.9706			

* Significantly different at $p \leq 0.05$.

TABLE 113. Summary of the statistical analysis for first negative impulse - Pre (FNIPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	370.9991	2	185.4995	0.40	0.672	N.S.
ERROR	12402.8345	27	459.3642			

* Significantly different at $p \leq 0.05$.

TABLE 114. Summary of the statistical analysis for first negative impulse time - Pre (FNITPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0163	2	0.0082	0.98	0.388	N.S.
ERROR	0.2249	27	0.0083			

* Significantly different at $p \leq 0.05$.

TABLE 115. Summary of the statistical analysis for positive impulse - Pre (PIPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	1591.7704	2	795.8852	0.77	0.471	N.S.
ERROR	27744.1900	27	1027.5626			

* Significantly different at $p \leq 0.05$.

TABLE 116. Summary of the statistical analysis for positive impulse time - Pre (PITPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0062	2	0.0031	0.49	0.617	N.S.
ERROR	0.1703	27	0.0063			

* Significantly different at $p \leq 0.05$.

TABLE 117. Summary of the statistical analysis for second negative impulse - Pre (SNIPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.2395	2	0.1197	0.01	0.992	N.S.
ERROR	412.1133	27	15.2635			

* Significantly different at $p \leq 0.05$.

TABLE 118. Summary of the statistical analysis for second negative impulse time - Pre (SNITPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0000	2	0.0000	0.08	0.919	N.S.
ERROR	0.0011	27	0.0000			

* Significantly different at $p \leq 0.05$.

TABLE 119. Summary of the statistical analysis for total positive impulse - Pre (TPIPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	478.8301	2	239.4150	0.18	0.834	N.S.
ERROR	35397.8694	27	1311.0322			

* Significantly different at $p \leq 0.05$.

TABLE 120. Summary of the statistical analysis for total positive impulse time - Pre (TPITPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0375	2	0.0188	0.91	0.413	N.S.
ERROR	0.5543	27	0.0205			

* Significantly different at $p \leq 0.05$.

TABLE 121. Summary of the statistical analysis for minimum ground reaction force - Pre (FMINPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	50867.4532	2	25433.7266	0.84	0.442	N.S.
ERROR	815248.9120	27	30194.4041			

* Significantly different at $p \leq 0.05$.

TABLE 122. Summary of the statistical analysis for time of minimum ground reaction force - Pre (TFMINPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0275	2	0.0138	0.76	0.476	N.S.
ERROR	0.4875	27	0.0180			

* Significantly different at $p \leq 0.05$.

TABLE 123. Summary of the statistical analysis for maximum ground reaction force - Pre (FMAXPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	970.3349	2	485.1675	0.01	0.993	N.S.
ERROR	1958125.4622	27	72523.1653			

* Significantly different at $p \leq 0.05$.

TABLE 124. Summary of the statistical analysis for time of maximum ground reaction force - Pre (TFMAXPRE).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0025	2	0.0013	0.27	0.768	N.S.
ERROR	0.1281	27	0.0047			

* Significantly different at $p \leq 0.05$.

TABLE 125. Summary of the statistical analysis for pre to post difference in first negative impulse (DIFFFNI).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	350.6781	2	175.3391	0.68	0.515	N.S.
ERROR	6954.5892	27	257.5774			

* Significantly different at $p \leq 0.05$.

TABLE 126. Summary of the statistical analysis for pre to post difference in first negative impulse time (DIFFFNIT).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0049	2	0.0025	0.72	0.497	N.S.
ERROR	0.0930	27	0.0034			

* Significantly different at $p \leq 0.05$.

TABLE 127. Summary of the statistical analysis for pre to post difference in positive impulse (DIFFPI).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	5029.1509	2	2514.5755	1.47	0.249	N.S.
ERROR	46330.8476	27	1715.9573			

* Significantly different at $p \leq 0.05$.

TABLE 128. Summary of the statistical analysis for pre to post difference in positive impulse time (DIFFPIT).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	[illegible].0047	2	0.0023	0.47	0.628	N.S.
ERROR	0.1331	27	0.0049			

* Significantly different at $p \leq 0.05$.

TABLE 129. Summary of the statistical analysis for pre to post difference in second negative impulse (DIFFSNI).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	27.0431	2	13.5216	0.73	0.493	N.S.
ERROR	502.4974	27	18.6110			

* Significantly different at $p \leq 0.05$.

TABLE 130. Summary of the statistical analysis for pre to post difference in second negative impulse time (DIFFSNIT).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0001	2	0.0000	0.65	0.532	N.S.
ERROR	0.0018	27	0.0001			

* Significantly different at $p \leq 0.05$.

TABLE 131. Summary of the statistical analysis for pre to post difference in total positive impulse (DIFFTPI).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	1354.6245	2	677.3122	0.46	0.633	N.S.
ERROR	39354.4940	27	1457.5739			

* Significantly different at $p \leq 0.05$.

TABLE 132. Summary of the statistical analysis for pre to post difference in total positive impulse time (DIFFTPIT).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0000	2	0.0000	0.00	0.999	N.S.
ERROR	0.3327	27	0.0123			

* Significantly different at $p \leq 0.05$.

TABLE 133. Summary of the statistical analysis for pre to post difference in total positive impulse (DIFFTPI).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	9554.3108	2	4777.1554	0.36	0.703	N.S.
ERROR	361916.7279	27	13404.3233			

* Significantly different at $p \leq 0.05$.

TABLE 134. Summary of the statistical analysis for pre to post difference in time of minimum ground reaction force (DIFFTFMIN).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0171	2	0.0085	0.49	0.619	N.S.
ERROR	0.4709	27	0.0174			

* Significantly different at $p \leq 0.05$.

TABLE 135. Summary of the statistical analysis for pre to post difference in maximum ground reaction force (DIFFMAX).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	76220.6357	2	38110.3179	0.66	0.524	N.S.
ERROR	1553890.5291	27	57551.5011			

* Significantly different at $p \leq 0.05$.

TABLE 136. Summary of the statistical analysis for pre to post difference in time of maximum ground reaction force (DIFFTFMAX).

Analysis of Variance

Source of Variation	SS	DF	MS	F	P	Sig*
GROUP	0.0135	2	0.0067	1.14	0.336	N.S.
ERROR	0.1604	27	0.0059			

* Significantly different at $p \leq 0.05$.

TABLE 137. Pearson product-moment correlation matrix for the dependent variables measured in the initial testing session.

	LBM	PBF	HTRCM	VELTO	GFOR	MAN	MAK	MAA	MAVN	MAVK	MAVA	MAVTN	MAVTK	MAVTA	VMXN	VMXK	VMXA	FRI	FRIT	PI	PIT	SNI	SNIT
MASS	0.90030	0.84487	-0.19071	0.23154	0.27076	0.06508	-0.17821	0.08810	-0.00089	0.14863	-0.23481	0.10398	0.17658	0.16570	0.13017	0.01282	-0.31448	0.33490	0.32280	0.70830	0.14588	0.84184	0.14673
LBM	1.00000	0.15234	0.07419	0.01203	0.28597	-0.11340	-0.23850	-0.00467	0.08029	-0.10379	-0.18531	0.16451	0.17885	0.10947	0.27342	0.16873	-0.23985	0.40698	0.31771	0.23593	0.18694	0.58642	0.16487
PBF		1.00000	0.51110	0.50525	0.08313	0.34286	0.03449	0.17121	-0.31698	-0.13902	0.19575	-0.08031	0.06592	0.18579	-0.21219	0.26971	-0.25656	0.01983	0.12873	0.05562	-0.01460	0.43902	0.01408
HTRCM			1.00000	0.88383	0.21753	-0.42857	-0.09858	-0.20087	0.30150	0.13654	0.20191	0.08009	-0.08369	-0.12816	0.04847	0.06484	0.15821	0.44695	-0.23983	0.42366	0.11253	-0.16241	0.02514
VELTO				1.00000	0.25285	-0.40013	-0.03806	-0.18744	0.33854	0.18096	0.28698	0.00477	-0.15378	0.26522	0.03406	0.14274	0.12783	0.44946	-0.24068	0.39171	0.08534	0.24504	0.11738
GFOR					1.00000	0.47899	[illegible]	-0.08833	0.43279	0.83503	0.38871	-0.74159	-0.74902	-0.43612	0.12522	0.18437	0.16835	0.11329	-0.37245	0.47850	-0.70740	0.22782	0.00761
MAN						1.00000	[illegible]	-0.01485	0.27508	0.82471	0.23868	[illegible]	-0.61198	-0.22231	0.26438	0.00640	0.26307	-0.25011	0.17389	-0.13851	-0.67086	0.24979	[illegible]
MAK							1.00000	-0.37508	0.17443	0.29115	0.67840	-0.60388	-0.72548	-0.65598	-0.05440	-0.09826	0.45611	-0.36832	-0.46483	-0.09097	-0.68591	0.05198	0.29212
MAA								1.00000	-0.21429	-0.14420	-0.61680	0.11348	0.18748	0.35642	-0.20958	-0.30968	-0.77628	0.15481	-0.06502	-0.04736	0.18072	0.10430	[illegible]
MAVN									1.00000	0.34031	0.17545	0.33847	0.32329	-0.24745	0.57674	0.47073	0.24457	-0.06622	0.04907	0.19814	[illegible]	0.20802	0.16877
MAVK										1.00000	0.50740	-0.85687	-0.80764	-0.44148	0.23632	0.51493	0.56088	0.04398	-0.48748	0.23500	-0.18031	-0.06556	0.02410
MAVA											1.00000	0.40241	-0.62572	-0.90831	0.00658	0.09722	0.67746	-0.14121	-0.33930	0.11972	-0.34635	0.22285	[illegible]
MAVTN												1.00000	0.85111	0.46204	-0.01128	-0.13293	-0.33516	0.24862	0.49375	-0.11793	0.87480	-0.07871	-0.10381
MAVTK													1.00000	0.84669	-0.03876	-0.15763	-0.81864	0.18504	0.56081	-0.19826	0.93676	-0.03518	0.13985
MAVTA														1.00000	0.01558	-0.07678	-0.50271	0.19056	0.32079	-0.07105	[illegible]	0.10240	-0.14979
VMXN															1.00000	0.72881	0.18230	0.12993	0.12135	0.18800	-0.10710	0.19176	-0.27924
VMXK																1.00000	0.41602	0.10695	0.04321	0.01372	[illegible]	[illegible]	[illegible]
VMXA																	1.00000	-0.18474	-0.16850	0.02852	0.51576	[illegible]	[illegible]
FRI																		1.00000	-0.29865	0.53471	0.32648	0.14951	-0.10298
FRIT																			1.00000	-0.27491	0.44344	0.01327	-0.18079
PI																				1.00000	[illegible]	0.02502	-0.13524
PIT																					1.00000	[illegible]	-0.13546
SNI																						1.00000	0.65533
																							1.00000

TABLE 137. Pearson product-moment correlation matrix for the dependent variables measured in the initial testing session (continued).

	TPI	TPIT	FMIN	FMAX	TFMIN	TFMAX	KRPTO	KRPTO5	KRPT1	KRPT2	KRPT3	KRPT4	KRPT5	ARPTO	ARPTO5
MASS	0.73004	0.29200	0.33414	0.40137	0.26983	0.22797	-0.22230	-0.13919	0.06321	-0.19004	-0.20803	-0.25339	-0.32134	-0.24126	-0.24137
LBM	0.67876	0.31196	0.50174	0.36749	0.20671	0.24597	-0.13999	0.00454	0.19800	0.01013	-0.05580	-0.06204	-0.11727	-0.03808	-0.03006
%BF	0.37350	0.07485	0.25514	0.40747	0.05964	0.06436	-0.27199	-0.30741	-0.22172	-0.43844	-0.33629	-0.44876	-0.48371	-0.47130	-0.49142
HTRCM	-0.17708	-0.09069	-0.36833	-0.12807	-0.12097	0.38595	-0.01192	0.12952	0.14792	0.29342	0.37511	0.40846	0.50789	0.26898	0.31272
VELTO	-0.20024	-0.12294	-0.40397	-0.10331	-0.16718	0.40395	0.10213	0.22116	0.17031	0.26230	0.43296	0.37711	0.46060	0.23714	0.27926
GFOR	-0.27577	-0.62384	-0.24278	0.59426	-0.64369	0.28884	0.29855	0.01645	0.05254	0.08782	0.19109	-0.00758	0.05050	-0.08164	0.02894
MAH	-0.35220	-0.59533	-0.16136	0.35408	-0.47804	-0.12945	0.36162	-0.06715	0.03734	-0.03465	0.13461	-0.00414	-0.00859	-0.46855	-0.38184
MAK	-0.60277	-0.65901	-0.26722	-0.11632	-0.46662	-0.18086	0.35022	0.14582	-0.01295	0.23990	0.19904	0.34167	0.11211	-0.17312	-0.12201
MAA	0.10439	0.04495	-0.16181	0.21334	-0.06809	-0.11145	-0.14478	-0.23049	-0.08446	-0.23100	-0.17095	-0.43177	-0.20603	-0.03168	0.03562
MAVH	-0.24627	-0.23268	-0.09241	0.07965	-0.35567	0.08925	0.06028	0.20965	0.11939	0.32257	0.24796	0.13611	0.26013	0.08887	0.29226
MAVK	-0.50816	-0.70219	-0.39071	0.48116	-0.72093	0.02408	0.23619	-0.13962	-0.06289	-0.01607	0.29251	0.20938	0.22468	-0.19166	-0.03720
MAVA	-0.43816	-0.61116	-0.25599	0.09985	-0.44660	0.05539	0.32214	0.11331	-0.05233	0.15101	0.15014	0.38228	0.27200	0.12521	0.18684
MAVTH	0.[illegible]0560	0.78863	0.34471	-0.34640	0.75044	0.01541	-0.38610	-0.16490	-0.13618	-0.26508	-0.34671	-0.12067	-0.09677	0.32337	0.19989
MAVTK	0.69423	0.86365	0.43508	-0.27834	0.79391	0.02685	-0.34981	0.01011	0.04542	-0.12741	-0.33067	-0.28655	-0.18713	0.23817	0.07267
MAVTA	0.42962	0.50801	0.22064	-0.07946	0.48038	-0.09410	-0.31861	-0.15934	0.03591	-0.14385	-0.18678	-0.40493	-0.27824	-0.01627	-0.11687
VMXH	0.09250	0.00712	0.11084	0.19070	-0.04820	-0.16299	-0.06810	0.04144	-0.07419	0.08337	0.01474	0.03080	-0.06337	0.08090	0.13504
VMXK	-0.05140	-0.09901	0.07199	0.18504	-0.20008	-0.01411	-0.02082	0.02905	0.04716	0.04850	0.17068	0.20492	0.16748	0.03589	-0.02624
VMXA	-0.43557	-0.38012	-0.10430	-0.09388	-0.32310	-0.06590	0.18810	0.00531	-0.06045	0.09907	0.17707	0.32141	0.20592	-0.03620	0.00053
FHI	0.23909	-0.01737	-0.32586	0.33481	-0.03071	0.50015	-0.20653	-0.27862	-0.13222	-0.15487	0.04171	-0.08758	-0.04298	-0.03523	-0.00991
FHIT	0.74229	0.87298	0.89017	-0.15811	0.73222	-0.13830	-0.26447	0.11287	0.06052	-0.16534	-0.34384	-0.29000	-0.23107	0.20289	0.11944
PI	-0.00571	-0.25309	-0.40082	0.48864	-0.30890	0.27802	-0.05526	-0.06613	-0.04134	0.05226	0.21369	-0.04494	0.10936	0.00413	0.15762
PIT	0.66939	0.82270	0.30004	-0.27309	0.81039	0.08221	-0.30868	-0.02587	0.04867	-0.13069	-0.25585	-0.15105	-0.10790	0.23770	0.11235
SHI	0.27218	0.00230	0.29508	0.19398	0.03706	0.10889	-0.15099	0.00747	0.15706	-0.08113	-0.01162	-0.01451	-0.09959	-0.24622	-0.36311
SHIT	-0.15769	-0.15788	0.07086	-0.24263	-0.07822	0.08764	-0.00628	0.23102	0.17908	0.15470	0.20178	0.30419	0.16823	-0.15349	-0.32189
TPI	1.00000	0.83284	0.73546	0.21459	0.75303	0.05205	-0.31165	-0.05263	0.07590	-0.25475	-0.37347	-0.35769	-0.33460	0.07846	-0.00980
TPIT		1.00000	0.73522	-0.26040	0.90679	-0.03968	-0.33766	0.06742	0.07283	-0.17474	-0.36072	-0.28179	-0.19932	0.25242	0.12396
FMIN			1.00000	-0.08264	0.66283	-0.09611	-0.20571	0.10590	0.12992	-0.10464	-0.34635	-0.22570	-0.23966	0.07981	0.00191
FMAX				1.00000	0.38036	0.00988	0.03140	-0.15648	-0.00209	-0.16021	-0.05970	-0.28666	-0.17762	-0.11787	-0.10048
TFMIN					1.00000	-0.04228	-0.18435	0.04032	0.04809	-0.18533	-0.36704	-0.21226	-0.28437	0.17357	0.07416
TFMAX						1.00000	-0.05217	-0.10773	-0.14369	-0.11214	-0.04260	-0.01308	0.05692	-0.01381	0.08039
KRPTO							1.00000	0.46349	0.42484	0.42565	0.35792	0.28524	0.24149	0.27042	0.37158
KRPTO5								1.00000	0.71465	0.70343	0.44427	0.33714	0.36364	0.40658	0.30067
KRPT1									1.00000	0.81964	0.58193	0.44729	0.57047	0.19573	0.09516
KRPT2										1.00000	0.76975	0.63509	0.69409	0.24353	0.18281
KRPT3											1.00000	0.71957	0.76588	-0.06243	-0.10549
KRPT4												1.00000	0.84971	0.02760	-0.06151
KRPT5													1.00000	0.16529	0.19038
ARPTO														1.00000	0.64775
ARPTO5															1.00000

TABLE 137. Pearson product-moment correlation matrix for the dependent variables measured in the initial testing session (continued).

	ARPT1	ARPT2	ARPT3	ARPT4	ARPT5	KRPPOS	KRPP1	KRPP2	KRPP3	KRPP4	KRPP5	ARPPOS	ARPP1	ARPP2	ARPP3	ARPP4	ARPP5
MASS	-0.25104	-0.19864	-0.32920	-0.32028	-0.34210	-0.14773	0.04013	-0.15867	-0.24115	-0.22808	-0.32815	-0.23537	-0.27408	-0.19844	-0.33291	-0.32446	-0.33665
LBM	-0.05095	-0.06434	-0.16602	-0.10993	-0.22904	-0.00929	0.21146	0.02928	-0.09630	-0.04488	-0.12771	-0.03372	-0.09982	-0.05911	-0.16346	-0.10692	-0.21254
PBF	-0.48340	-0.34300	-0.43677	-0.39420	-0.36114	-0.29656	-0.30099	-0.40565	-0.35392	-0.42445	-0.48269	-0.47275	-0.42898	-0.34251	-0.44991	-0.39086	-0.30001
HTHCM	0.36976	0.07823	0.13964	0.22989	0.09254	0.15669	0.17912	0.30363	0.37915	0.41356	0.47821	0.29464	0.36123	0.08051	0.14641	0.23697	0.11745
VELTO	0.33191	0.08503	0.16309	0.21412	0.11947	0.23753	0.20561	0.20927	0.40685	0.39301	0.43172	0.25433	0.32607	0.08282	0.17044	0.22390	0.13398
GFOR	0.01179	-0.00747	-0.07914	-0.16797	-0.14666	0.01630	0.10329	0.07279	0.10481	-0.00674	0.05503	0.00894	0.02718	-0.04391	-0.08972	-0.16151	-0.12662
MAH	-0.43109	-0.32227	-0.31754	-0.44053	-0.36272	-0.00225	0.06677	-0.04634	0.13649	-0.00788	-0.05204	-0.38903	-0.36299	-0.33011	-0.32090	-0.44164	-0.36320
MAK	-0.11083	-0.01182	0.02113	0.06309	-0.01267	0.18125	0.05515	0.24464	0.23022	0.33719	0.14557	-0.13072	-0.05139	-0.01263	0.03347	0.06656	0.00742
MAA	-0.10262	0.05918	0.01791	-0.07797	0.00654	-0.21994	-0.12880	-0.20141	-0.20837	-0.44005	-0.21419	0.03281	-0.12416	0.06250	0.00718	-0.00493	0.04745
MAVH	0.25025	0.22443	0.30526	0.10918	0.14633	0.18253	0.14266	0.30874	0.21317	0.11231	0.24277	0.24228	0.17248	0.17802	0.30563	0.18989	0.15997
MAVK	-0.08386	-0.10013	0.04706	-0.06694	-0.01080	-0.15218	-0.02702	-0.01981	0.31313	0.20361	0.20597	-0.04563	-0.09224	-0.12991	0.04582	-0.06568	0.00289
MAVA	0.20249	0.13481	0.23585	0.33509	0.17549	0.12463	0.02606	0.20691	0.21144	0.38045	0.20391	0.10026	0.25502	0.13003	0.24359	0.34251	0.21085
MAVTH	0.21041	0.10319	0.09226	0.22164	0.20198	-0.15249	-0.16798	-0.22421	-0.35331	-0.09167	-0.12557	0.20226	0.17717	0.14121	0.10035	0.22315	0.18630
MAVTK	0.12516	0.06875	0.00283	0.08048	0.08042	0.00253	-0.01682	-0.10810	-0.38530	-0.24794	-0.19473	0.07801	0.08091	0.09330	0.00330	0.08021	0.03557
MAVTA	-0.06663	-0.09614	-0.15997	-0.24340	-0.11241	-0.16142	-0.04172	-0.10158	-0.10683	-0.39505	-0.29271	-0.09808	-0.10896	-0.09106	-0.16704	-0.24463	-0.16530
VMEH	0.28021	0.30193	0.36976	0.31271	0.33523	-0.01080	-0.07424	0.05499	-0.00336	0.01622	-0.09015	0.13988	0.20230	0.26705	0.36882	0.30967	0.34010
VMEK	0.06601	0.08653	0.29417	0.18812	0.17003	-0.08774	0.05084	0.06469	0.14834	0.19207	0.13511	-0.04980	-0.00803	0.05516	0.28860	0.16547	0.19249
VMEA	0.05507	-0.09769	0.10421	0.17197	0.06216	0.00543	0.00447	0.14993	0.23475	0.32532	0.19484	-0.01736	[illegible]	-0.10619	0.19372	0.17595	0.08556
FRI	0.04438	-0.10061	-0.07047	-0.06466	-0.04165	-0.28005	-0.11972	-0.15196	0.00376	-0.00898	-0.07902	-0.01739	[illegible]	-0.09669	-0.06273	-0.05351	-0.05520
FRIT	0.10444	0.07630	0.09094	0.07689	0.02941	0.10309	-0.00806	-0.13125	-0.32665	-0.29864	-0.25151	0.13699	0.06800	0.08021	0.07634	0.07103	0.02796
PI	0.12842	-0.06839	-0.09706	-0.16680	-0.12011	-0.01508	0.01351	0.04615	0.10003	-0.02026	0.08708	0.14163	0.13572	-0.09504	-0.10042	-0.15848	-0.11597
PIT	0.14126	0.03533	-0.03302	0.10289	0.04792	-0.01473	-0.00831	-0.11386	-0.28201	-0.13094	-0.11649	0.12282	0.10230	0.06699	-0.02942	0.10628	0.03743
SRI	-0.42862	-0.19584	-0.32514	-0.36311	-0.35742	-0.01171	0.15530	-0.08626	-0.04693	0.01559	-0.10849	-0.37509	[illegible]	-0.20217	-0.31765	-0.36518	-0.34246
SRIT	-0.35605	-0.17221	-0.24072	-0.18250	-0.21004	0.21641	0.22682	0.14730	0.18026	0.38691	0.17329	-0.32474	-0.31717	-0.17272	-0.24154	-0.19290	-0.18509
TPI	0.00005	-0.04265	-0.12562	[illegible]	-0.11949	-0.04948	0.01519	-0.20771	-0.38532	-0.33447	-0.35000	0.01014	[illegible]	-0.03088	-0.13480	-0.07775	-0.12059
TPIT	0.12872	0.06070	0.02896	0.09738	0.03603	0.06896	0.00135	-0.13957	-0.38493	-0.24304	-0.21685	0.14076	0.08583	0.07992	0.02242	0.09518	0.03167
FMIN	0.00358	0.05709	0.03122	0.01044	-0.03393	0.00324	0.06812	-0.05903	-0.33137	-0.23009	-0.24760	0.01680	-0.03740	0.08048	0.01867	0.00470	-0.02796
FMAX	-0.10023	-0.11669	-0.11961	-0.21597	-0.14267	-0.13914	-0.00067	-0.17203	-0.06760	-0.26872	-0.10304	-0.09944	-0.10810	-0.14690	-0.13032	-0.21025	-0.12772
TFMIN	0.09905	0.02734	-0.07125	0.08064	-0.00093	0.03298	-0.00726	-0.13031	-0.37131	-0.19720	-0.28610	0.10229	0.07339	0.06730	-0.07026	0.08324	-0.01167
TFMAX	0.08614	0.06614	-0.11041	-0.06662	-0.05980	-0.12087	-0.15441	-0.09045	-0.07701	0.01253	0.04308	0.06318	0.09133	0.05775	-0.10739	-0.05428	-0.07275
KRPTO	0.35544	0.22923	0.11328	-0.05551	0.09082	0.46259	0.47829	0.48187	0.35614	0.25203	0.27633	0.17368	0.37438	0.21015	0.11043	-0.04585	0.11236
KRPTOS	0.36207	0.45843	0.32952	0.22794	0.22225	0.98839	0.75018	0.69721	0.43657	0.31447	0.37096	0.31824	0.30720	0.44232	0.33372	0.22666	0.26904
KRPT1	0.11375	0.13660	0.07838	-0.10610	-0.05161	0.73476	0.97951	0.84122	0.67738	0.43282	0.38540	0.09821	0.10283	0.13494	0.08286	-0.10491	-0.03706
KRPT2	0.24656	0.24609	0.25702	0.06601	0.08384	0.71641	0.82821	0.98550	0.79579	0.61185	0.72179	0.18484	0.23374	0.24034	0.26457	0.05596	0.09769
KRPT3	-0.09396	-0.11953	0.01382	-0.17410	-0.06897	0.45316	0.66702	0.77018	0.98402	0.71826	0.76113	-0.09510	-0.10495	-0.13533	0.01993	-0.17694	-0.03879
KRPT4	-0.07112	-0.08602	0.00128	-0.01343	-0.07149	0.34081	0.46304	0.63812	0.74759	0.99288	0.85599	-0.06217	-0.08070	-0.08734	0.03256	-0.01618	-0.03543
KRPT5	0.10627	0.04073	0.14944	-0.00757	0.01823	0.39017	0.56344	0.70748	0.78785	0.84074	0.99466	0.17380	0.09176	0.04104	0.15900	-0.00069	0.03346
ARPTO	0.73545	0.67269	0.60674	0.55956	0.57940	0.41804	0.23041	0.25675	0.00108	0.02598	0.16274	0.63796	0.71618	0.67281	0.60614	0.56505	0.59593
ARPTOS	0.80356	0.72347	0.60466	0.46023	0.50416	0.31871	0.15356	0.19641	-0.08606	-0.06223	0.16656	0.99269	0.87839	0.72373	0.58366	0.46504	0.50092
ARPT1	1.00000	0.79865	0.66311	0.55667	0.62360	0.37020	0.18441	0.26737	-0.06238	-0.07205	0.09983	0.90769	0.98111	0.79963	0.65844	0.60389	0.62267
ARPT2		1.00000	0.78105	0.72197	0.80000	0.44787	0.15539	0.23271	-0.08647	-0.08916	0.04258	0.73950	0.79469	0.99660	0.77933	0.72069	0.79392
ARPT3			1.00000	0.86894	0.86865	0.30270	0.09464	0.26802	0.07162	0.01036	0.12603	0.58030	0.66649	0.77309	0.99878	0.86779	0.86643
ARPT4				1.00000	0.87170	0.20154	-0.09145	0.08782	-0.11080	-0.02348	-0.02574	0.46592	0.61307	0.72508	0.87104	0.99941	0.88943
ARPT5					1.00000	0.21105	-0.06486	0.09423	-0.03696	-0.07505	-0.00961	0.52590	0.62879	0.79520	0.86107	0.86694	0.99345
KRPPOS						1.00000	0.76872	0.71009	0.46425	0.31717	0.40715	0.33329	0.40344	0.43562	0.30520	0.20058	0.25503
KRPP1							1.00000	0.84538	0.65396	0.45196	0.59565	0.14502	0.15643	0.15442	0.10388	-0.00891	-0.04246
KRPP2								1.00000	0.79543	0.62000	0.73185	0.19439	0.26316	0.22977	0.27612	0.08994	0.10055
KRPP3									1.00000	0.74545	0.78559	-0.07172	-0.06415	-0.09783	0.07863	-0.12080	-0.02918
KRPP4										1.00000	0.84356	-0.06544	-0.07608	-0.07931	0.03449	-0.02310	-0.04086
KRPP5											1.00000	0.16964	0.07084	0.04636	0.13654	-0.02680	0.00607
ARPPOS												1.00000	0.88477	0.74027	0.57699	0.46926	0.52199
ARPP1													1.00000	0.80093	0.66303	0.62170	0.62846
ARPP2														1.00000	0.77386	0.72681	0.78636
ARPP3															1.00000	0.87036	0.86057
ARPP4																1.00000	0.88392
ARPP5																	1.00000

TABLE 138. Intercorrelations among selected variables from the IKE, IPF and VBJ performances.

	HTRCM	VELTO	GFOR	FMAX	MAH	MAK	MAVH	MAVTH	MAVK	MAVTK	MAVA	MAVTA	PI	PIT	TPI	TPIT	KRPTO	KRPT1	KRPT3	KRPT5	ARPTO	ARPT1	ARPT4
MASS	-0.19071	-0.23154	0.27076	0.48137	0.06508	-0.17821	-0.08059	0.10398	-0.14863	0.17686	-0.23481	0.16570	0.20830	0.14588	0.73004	0.29200	-0.22230	0.08321	-0.20803	-0.32134	-0.24125	-0.25104	-0.32825
HTRCM	1.00000	0.88383	0.21753	-0.12507	-0.42857	-0.09856	0.30180	0.08009	0.13854	-0.00369	0.20191	-0.12816	0.42366	0.11253	-0.17708	-0.09059	-0.01192	0.14792	0.37511	0.50789	0.26896	0.36976	0.22958
VELTO		1.00000	0.25285	-0.10331	-0.40013	-0.03588	0.33584	0.00477	0.18098	-0.18378	0.28698	-0.26522	0.39171	0.06534	-0.20024	-0.12294	0.10213	0.17031	0.43298	0.46080	0.23716	0.33191	0.21412
GFOR			1.00000	0.59426	0.42899	0.37388	0.43279	-0.74189	0.63803	-0.74902	0.38821	-0.43612	0.47850	-0.70740	-0.27577	-0.82384	0.28886	0.05284	0.19109	0.05050	-0.08164	0.01179	-0.16797
FMAX				1.00000	0.35409	-0.11632	0.07965	-0.34640	0.48116	-0.27834	0.09985	-0.07946	0.40864	-0.27309	0.21459	-0.26040	0.03140	-0.00209	-0.05970	-0.17762	-0.11797	-0.10023	-0.21597
MAH					1.00000	0.43076	-0.27808	-0.72217	0.82471	-0.81198	0.23880	-0.22231	-0.13851	-0.67060	-0.35220	-0.59533	0.36182	0.03734	0.13451	-0.08559	-0.46665	-0.43189	-0.44053
MAK						1.00000	0.17443	-0.80386	0.29116	-0.72548	0.82840	-0.65596	-0.09097	-0.68891	-0.60277	-0.65901	0.35022	-0.01295	0.19984	0.11211	-0.17332	-0.11883	0.06309
MAVH							1.00000	-0.33847	0.34031	-0.32329	0.17845	-0.24245	0.39514	-0.35553	-0.24827	-0.23268	0.08028	0.11939	0.24798	0.25813	0.06887	0.25025	0.18918
MAVTH								1.00000	-0.68667	0.85111	-0.40241	0.48204	-0.11793	0.87480	0.60560	0.78863	-0.38610	-0.13619	-0.34671	-0.09877	0.32337	0.21041	0.22154
MAVK									1.00000	-0.80764	0.50740	-0.44148	0.23500	-0.76031	-0.50816	-0.70219	0.23619	-0.06289	0.29251	0.22668	-0.19166	-0.08386	-0.06694
MAVTK										1.00000	-0.62572	0.64569	-0.19526	0.93676	0.69423	0.86356	-0.34981	0.04642	-0.33067	-0.18713	0.23917	0.12816	0.08045
MAVA											1.00000	-0.90831	0.11972	-0.64635	-0.43816	-0.51195	0.32214	-0.05233	0.15014	0.27200	0.12521	0.20249	0.33509
MAVTA												1.00000	-0.07105	0.56677	0.42962	0.50801	-0.31861	0.03591	-0.16670	-0.27824	-0.01827	-0.06653	-0.24340
PI													1.00000	-0.13149	-0.00671	-0.25308	-0.05526	-0.04134	0.21369	0.10936	0.00413	0.12042	-0.16680
PIT														1.00000	0.66939	0.82270	-0.30888	0.04867	-0.25585	-0.10790	0.23770	0.14126	0.10259
TPI															1.00000	0.83284	-0.31165	0.07690	-0.37347	-0.33460	0.07846	0.00005	-0.08065
TPIT																1.00000	-0.33766	0.07283	-0.35072	-0.19932	0.25242	0.12872	0.09738
KRPTO																	1.00000	0.42454	0.35792	0.24149	0.27042	0.35544	-0.05551
KRPT1																		1.00000	0.68193	0.57047	0.19973	0.11375	-0.10610
KRPT3																			1.00000	0.76685	-0.06243	-0.09396	-0.17410
KRPT5																				1.00000	0.16529	0.10627	-0.00757
ARPTO																					1.00000	0.73645	0.55956
ARPT1																						1.00000	0.59667
ARPT4																							1.00000