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Effects of Short-Term Isokinetic Training on Standing Long-Jump Performance in Untrained Men

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ABSTRACT

The purpose of this study was to examine the effects of a 6-week isokinetic training program on quadriceps and hamstrings peak torque (PT) and standing long-jump (SLJ) performance. Twelve untrained men (age 31.4 ± 4.2 years, mean ± *SD*) were tested at a velocity of 1.75 rad·s^{-1} (100°·s^{-1}), before and after a 6-week control period and on completion of a 6-week training program. Training consisted of 3 sets of 10 repetitions, 3 days per week, for 6 weeks. Repeated-measures analysis-of-variance analyses revealed that quadriceps PT increased, on average, by 10.5% as a result of training ($p < 0.01$). No significant changes in hamstrings PT ($p = 0.062$) and SLJ performance occurred as a result of training ($p > 0.05$). The major finding of this study was that PT gains subsequent to isokinetic resistance training did not influence functional performance. That open-chain training did not affect the performance of a closed-chain activity is unsurprising, but on these grounds of nonfunctionality, the use of moderate velocity isokinetic dynamometry in rehabilitation and performance assessment for closed-chain sports needs addressing in future research.

Key Words: specificity, peak torque

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Introduction

Isokinetic movements have widespread use in performance testing, rehabilitation, and for athletic training. Their perceived advantage over other strength training procedures is that they allow the muscle to contract at maximal force throughout the full range of motion, thereby providing a greater training stimulus (15). The major problem with most isokinetic machinery is that only open-chain exercises can be performed. Given that sports movements are predominantly closed-chain, one wonders whether isokinetics should be the chosen exercise in performance tests, rehabilitation, or training, since the specificity of training principle (12) will not be supported.

In its favor, isokinetic resistance training has been shown to produce many beneficial adaptations in muscle strength, power, enzyme activities, and fiber composition (14, 17, 22, 29). But, whether such adaptations will prove productive to the sportsperson, should they be in rehabilitation or a particular training phase of a periodized program, remains to be seen.

We decided to test the effect of isokinetic training on athletic performance using a closed-chain, functional task. It was felt that the findings of the study would have practical significance to the athlete undergoing rehabilitation, those athletes who have access to isokinetic dynamometers for training purposes, and also those athletes/coaches who are interested in isokinetics for the purposes of performance assessment.

Methods

Subjects

Twelve healthy men from the UK Defence Services Medical Rehabilitation Centre participated in the study. All subjects were moderately active servicemen participating in various recreational activities and their physical characteristics are shown in Table 1. None had previously engaged in a regular, systematic resistance training program. Subjects were instructed to maintain their habitual level of activity throughout the trial period.

Test Procedures

Generic Test Procedures. Stature, body mass, and skinfolds were measured and recorded for each subject. Percentage of body fat was estimated using the sum of 4 skinfolds on the basis of the equations of Durnin and Womersley (10). Subjects completed a standard

Table 1. Subject's physical characteristics.

Variable	Mean *SD*	Range
Age (y)	31.4 ± 4.2	25–37
Stature (cm)	177.5 ± 5.5	168–188
Body mass (kg)	75.0 ± 7.3	63–83
Body fat (%)	11.2 ± 2.2	7.4–15.8

warm-up by cycling for 5 minutes, followed by a series of stretching exercises for the quadriceps and hamstrings. Subjects then performed the isokinetic test protocol for the quadriceps and hamstrings. After a 3-minute recovery, subjects were tested for standing long-jump (SLJ) performance.

Isokinetic Strength Measurements. Isokinetic peak torque (PT) of the right and left quadriceps/hamstrings was measured using a Technogym® REV 7000 dynamometer (Technogym SpA, 47035, Gambettola, Italy), interfaced with a Technogym data reduction system using an ASEM IBM-compatible computer. The REV 7000 system has only been shown to be a reliable instrument for torque generated by the quadriceps and hamstrings during concentric and eccentric loading at $60°\cdot s^{-1}$, $100°\cdot s^{-1}$, and $180°\cdot s^{-1}$ (23). An intermediate testing and training velocity of $100°\cdot s^{-1}$ was selected for all subsequent sessions because of it being a validated training speed, one that is typical of isokinetic testing and training protocols, and a speed representative of normal strength training exercises.

In the present study, quadriceps PT is defined as the highest torque produced during movement of 90° to 0° of single leg extension. Hamstrings PT is defined as the highest torque produced during movement of 0° to 90° of single leg flexion. PT has been shown to be a reliable measurement (23) and its use in isokinetic tests has been accepted in critical reviews (28, 9).

Tests were conducted in accordance with the protocol described by Tomberlin et al. and Perrin (28, 24). Each set consisted of 5 consecutive, reciprocal quadriceps and hamstrings contractions without pause. Subjects performed 5 submaximal warm-up contractions followed by a 1-minute recovery. Subjects then performed a test set of 5 maximal voluntary repetitions. After a 5-minute rest (walking and recovery stretching) the same protocol was performed on the opposite leg. The left leg was tested first on all occasions.

SLJ Task. Functional lower-extremity performance was assessed by a SLJ for distance test. This particular test was used because it is thought to represent functional sports performance tasks (1), requires little skill (30), and is heavily dependent on the muscular functions of strength and power (23).

Tests were performed on a rubberized surface utilizing a tape measure and zero mark indicators. To exclude the contribution of arm swing, arms were folded across the chest. Subjects performed 3 warm-up jumps to familiarize themselves with the technique and then performed 3 maximal efforts with a 45-second recovery between each trial. Jump distance was measured to the nearest centimeter by observation from zero mark to rear-most heel on landing. The best trial was used for statistical analysis.

Test–retest intraclass correlation coefficients after habituation with the procedures were $R \geq 0.93$ for all tests.

Training Procedures

Before each training session warm-up, isokinetic stabilization and alignment, range of motion settings, and gravity correction were performed in accordance with the testing procedures. All training was performed at $100°\cdot s^{-1}$.

Warm-up contractions comprised 4 submaximal and 1 maximal effort, followed by a 1-minute recovery. Subjects then performed 3 sets of 10 maximal voluntary contractions of the quadriceps and hamstrings. A 2-minute recovery was imposed between sets. After a 5-minute rest the same protocol was performed on the opposite leg. The left leg was exercised first during all training sessions. All training sessions were supervised. Posttraining tests were conducted 48 hours after the final training session to avoid any residual exercise effects.

Isokinetic training compliance for the 12 subjects was greater than 95%.

Approach to the Problem and Experimental Design

Our study intended to address the effectiveness of short-term, open-chain isokinetic training on the performance of a closed-chain exercise test. This approach was motivated by the fact that isokinetic modalities are still often used in sports rehabilitation (2) and performance testing environments (18), and by athletes who have access to such devices for training, even though most sports are based on closed-chain activities. We chose to use untrained men as subjects because the training period was delimited to only 6 weeks. Given the rapid adaptation response of untrained individuals, we felt that it would be possible to show significant strength improvements, even though muscular adaptations would not be fully realized within this timescale. Our intention was to find out if any strength improvements shown by the isokinetic dynamometer were meaningfully related to performance in the SLJ test.

Statistical Analyses

All analyses were carried out using the statistical package SPSS 9.0 for Windows (SPSS, Chicago, IL). Standard descriptive statistics, consisting of means and standard deviations (*SD*), were used to characterize the subject population. None of the variables showed

Table 2. Changes in peak torque and standing long-jump distance across the study (mean ± *SD*).

Variable	T1*	T2	T3
QR (N·m)	202 ± 37	196 ± 28	214 ± 28
QL (N·m)	209 ± 33	203 ± 30	227 ± 27
HR (N·m)	115 ± 19	111 ± 13	120 ± 14
HL (N·m)	112 ± 22	115 ± 19	123 ± 25
SLJ (cm)	215 ± 23	217 ± 28	222 ± 24

* T1, precontrol; T2 = postcontrol/pretraining; T3 = posttraining; Q = quadriceps; H = hamstrings; R = right; L = left; SLJ = standing long jump.

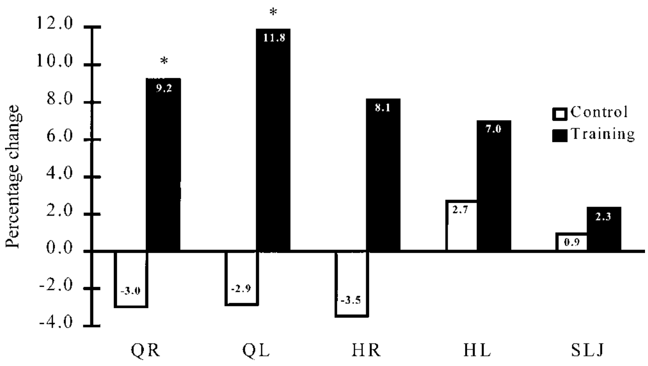

Figure 1. Percentage change in standing long jump and peak torque by muscle group by body side. *, Significant training period effect ($p < 0.01$). Q, quadriceps; H, hamstrings; R, right; L, left; SLJ, standing long jump.

significant differences to a normal distribution following a Kolmogorov–Smirnov goodness-of-fit test ($p > 0.05$).

A 3-way repeated-measures analysis of variance (ANOVA) was used to test the efficacy of the isokinetic exercise training program. The independent variables were muscle group, body side (symmetry), and time. PT was the dependent variable. Simple effects (27, 16) and post-hoc Tukey analyses were used to examine the significant main effects and interactions.

Absolute changes (Δ) in PT were also used as a summary measure for each subject (21) in a 3-way repeated-measures ANOVA. Separate Δ were calculated for the control period by subtracting the precontrol values from the postcontrol values, and for the training period by subtracting the pretraining values from the posttraining values. These Δ values were used to determine whether any changes over the training period were significantly different from those over the control period. It has been suggested that this method of unconditional inference may be used to quantify meaningful strength gains beyond the inherent variability associated with isokinetic dynamometry (26).

A 1-way repeated-measures ANOVA was used to assess whether there were any changes in SLJ distance across the study. Significance for all tests was assumed at $p \leq 0.05$.

Results

Changes in isokinetic peak torque (N·m) for the 2 different muscle groups by body side and SLJ distance over the study period are shown in Table 2. Delta values are shown in Figure 1. The main body-side effect and interactions involving this independent variable were not significant ($p > 0.05$), indicating that any alterations in peak torque were symmetric. As expected, PT values for the quadriceps were significantly higher than the hamstrings whenever they were measured ($p < 0.01$).

A significant main time effect ($p < 0.01$) and muscle-by-time interaction ($p < 0.05$) indicated that PT had changed during the study period. Both the simple effects and post-hoc Tukey analyses revealed that none of the changes in PT over the control period was statistically significant ($p > 0.05$). In contrast, PT increased for both the left and right quadriceps over the training period ($p < 0.01$). The increases in left (7.4 N·m) and right hamstrings (9.4 N·m) PT did not reach statistical significance, but a strong trend was suggested ($p = 0.062$).

Comparison of Δ values indicated that PT was reduced over the control period for most of the separate measures (see Figure 1). However, these changes were within the experimental error associated with the measurement of this variable ($p > 0.05$). In contrast, the change seen in the quadriceps' PT over the training period was significant when considering the aforementioned changes over the control period ($p < 0.01$). Although the right hamstring PT appeared to increase as a result of training, the left did not ($p > 0.05$). Collectively, the changes seen in the hamstrings over the training period did not reach statistical significance when compared to the control period, although a strong trend was again suggested ($p = 0.093$).

No significant differences were observed in SLJ performance over time ($p > 0.05$).

Discussion

The increases in isokinetic PT in this investigation are consistent with those found by other investigators (9, 11, 25, 31). These findings indicate that the present short-term training program was at least effective in improving quadriceps isokinetic PT. Such a training effect is interesting when examined relative to SLJ performance because no significant differences in control vs. training-period SLJ distance were found. Therefore, the major finding of this study was that strength gains subsequent to isokinetic resistance training do not influence a simple functional performance task, and is in agreement with earlier work (3, 8, 20). The underlying mechanisms that may account for this finding are explored in the following paragraphs.

The quadriceps and hamstrings PT gains reported in this study resulted from isokinetic *concentric* muscle contractions. In contrast, the functional task, the SLJ, involved a stretch-shortening cycle, that is, a concentric muscular action immediately preceded by an eccentric contraction. It is plausible that the limiting factor to improved jump performance was an absence of eccentric loading during training. This may have invoked a nonspecific adaptation to the functional task.

The ground contact phase of a SLJ takes about 350 ms to complete (22), a duration long enough to create large ground reaction forces. It is plausible that with this relatively long ground contact period (foot contact in sprinting <100 ms) the generation of large forces is one of the limiting factors of the task. And, given that isokinetic training resulted in improvements in the subjects' ability to generate greater joint torques, this form of training could positively influence SLJ performance. However, researchers have estimated that many functional activities occur at speeds greater than $300°·s^{-1}$ (19). The angular velocity of $100°·s^{-1}$ used in this study may well have induced a training adaptation nonspecific to the requirements of SLJ performance. In other words, the training-induced increased force-generating capacity of the subjects was unproductive in the performance of the SLJ because the ground reaction force could not be developed at a high enough rate. Whether a higher training speed might have produced improvements in SLJ performance and, therefore, justify the use of isokinetic modalities for the training and rehabilitation of closed-chain activities, is worthy of further attention.

Several research groups have stated that quadriceps and hamstrings strength and power are critical in a variety of jumping tests (4, 6, 7, 13). As the isokinetic training protocol in the current study resulted in an increase in PT levels, the lack of improvement in the jumping test might seem surprising. However, SLJ performance may well be governed by the neuromuscular coordination strategy used to generate the ground reaction force and not by the maximal torque that can be produced at any one time at any one joint. The isokinetic dynamometer does an excellent job of isolating joint movements and the muscles that can influence the torque production at those joints. Furthermore, none of the mechanical advantages (5) of bi-articular musculature such as the rectus femoris and hamstring muscles, can be realized in such a restricted posture. Thus, it is possible that the isolating nature of the training protocol was another reason for the lack of improvement in SLJ performance, even when knee joint flexion/extension PTs had been increased through training. Whether isokinetic squat training, which utilizes cocontraction of the hamstring and vastus muscle groups, would have produced better jumping effects is an interesting question, and worthy of future consideration.

This study indicated that isokinetic training improved the strength levels of the quadriceps femoris but not the hamstrings muscle group. It also showed that any strength increases were not concomitant with improvements in a more functional task, the SLJ. It is felt that the isokinetic training may only have improved force development capacity and not the rate at which force could be developed. Second, it is possible that training at such a slow joint angular velocity caused neuromuscular adaptations that were nonspecific to the jumping task. In addition, the isolating nature of the isokinetic dynamometer probably placed a nonspecific neuromuscular demand on each subject such that the significant intermuscular coordination element of jumping was not represented.

Practical Applications

That the training program did not influence jumping performance, yet showed strength improvements on the isokinetic dynamometer, leads to some practical applications.

Short-term isokinetic training does seem to improve the strength of thigh musculature; however, isokinetic test protocols should not necessarily be used to infer the functional capacity of the quadriceps and hamstrings in dynamic performances. Closed-chain activities such as the SLJ do not respond well to moderate-velocity open-chain training, and are probably best improved by closed-chain training exercises.

Classic open-chain isokinetic training programs lack specificity to the dynamic capabilities of the neuromuscular system in sport-specific activities, mainly owing to their inability to represent multijoint actions. Multijoint activities require training with multijoint exercises.

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