The anatomical and biomechanical structure of the trunk is extremely complex and, consequently, measuring trunk muscle strength has been problematic. As a consequence, the evaluation of the trunk musculature has not been as extensive as research on peripheral muscle groups, such as the hamstrings and quadriceps. During the last 10 years, technological advances have allowed for more sophisticated and accurate torque measurements using isokinetic equipment (8,11). This has resulted in a proliferation of research concerning the measurement of the trunk muscle strength for sedentary population groups (9,13,14,17-19).

There is, however, less information available about trunk strength of athletes. Since the trunk comprises approximately 50% of total body mass (19), the control of the trunk during sports events is important. Soccer, tennis, judo, and gymnastics involve trunk movements in conjunction with the extremities. Clinicians may need to determine that trunk muscle strength is appropriate for specific sports activities.

Andersson et al (1) investigated 71 (57 male and 14 female) Swedish national elite athletes from four different sports. The male gymnasts showed significantly higher peak values in hip flexion compared with all other sports categories. The position for peak torque occurred earlier in the movements for the athletes, especially for the gymnasts in extension movements and for tennis players in flexion movements. It was concluded that the differences between athletes were due to sports specificity and long-term systematic training.

Hakkinen (8) also measured trunk flexor and extensor force in 11 male and nine female basketball players and the results of the study found that the male basketball players produced higher values in absolute maximal strength and explosive power. When values were related to body mass and in time needed to produce the same relative levels in the force time curves, significant sex differences were found. These differences were attributed not only to sex differences but also to differences in the volume and the type of strength and power training.

Preliminary results from Soldati et al (16) emphasized the high levels of extensor muscle strength for groups of boxers, weight lifters, wrestlers, and body builders compared with a sedentary population, but similar flexor muscle strength was found between the athletic groups and the sedentary population. In another study, isokinetic strength was measured at four different velocities for judo players and cyclists (10) and results showed judo players had significantly higher peak torques, aver-
Results show that football and soccer players were stronger for flexor trunk strength than the running and recreation groups.

METHODS AND PROCEDURES

Subjects

Forty-six male varsity athletes and 15 recreationally active subjects between the ages of 18 and 28 years participated in the study. The recreation group and the three sports groups, Canadian football players (N=15), middle and long distance runners (N=15), and soccer players (N=16), were all volunteer participants. All varsity athletes must have trained and competed for their respective team for at least 1 year and within the last 2 years. The comparison group, consisting of university students, were recreationally active but not engaged in any systematic training program, e.g., weight training or running. Any subject who had experienced a low back injury within the last 12 months, which was sufficient to prevent normal daily activities, was excluded from the study. All subjects were asked to refrain from vigorous physical activity 24 hours before testing.

Test Procedure

Subjects were informed of the purpose of the study and that all results would be confidential. A signed consent form acknowledged information on the benefits and risks associated with trunk muscle strength testing. Body mass, height, chest, and waist girth/circumferences were recorded as outlined by the Canadian Standardised Test of Fitness (5).

The subjects were positioned in the center of the adjustable seat of a KinCom trunk testing dynamometer (Chattecx Corporation, Chattanooga, TN). The pelvis was stabilized by a sacral pad and two curved anterior pelvic pads. The ankles were secured with two Velcro® straps, which maintained a knee angle of 90° throughout the test.

The center of rotation of the lever arm was aligned with the highest point of the iliac crest in the midline of the trunk. With the subject sitting upright, the force application pad was aligned vertically with the body of the sternum. Horizontal and vertical displacement of the lever arm from the center of rotation was measured and entered into the computer. For consistency, the level of the force application pad was the same for the posterior trunk extensor testing.

To prevent any jerking movement from the arms, the subjects were instructed to interlace the fingers and rest their arms on the thighs. In addition, the subjects were requested to maintain a neutral head position throughout the testing procedure by looking straight ahead at the door in front of them. Once trunk flexion testing was completed, the force application pad was removed and placed behind the subject for extension testing.

Prior to and at the end of the study, the dynamometer was calibrated by suspending standardized weights on the lever arm through a 0° (upright position) and -20° extension.

FIGURE. Schematic diagram of the KinCom dynamometer and the total range of motion (60°; 40° of flexion, 0° upright position, and -20° of extension; a) strain gauge; b) lever arm; c) sacral pad; d) pelvic restraint pads; and e) adjustable seat.
range of motion. This resulted in an error of force measurement of less than 1%. Prior to each test, the dynamometer was calibrated according to manufacturer’s instructions.

Test Protocol

Peak torque was measured as the greatest torque developed during any one of the six alternating contractions and was considered a representation of maximum strength (1, 15, 18, 19). The order of testing for back and abdominal strength was randomized to prevent dependent ordering effect. Before any maximal testing, each subject performed a preliminary warm-up set of three to four submaximal and maximal contractions through the 60° range of motion. The order of the reciprocal eccentric and concentric contractions was also randomized. A 3-minute rest separated each of the flexor and extensor reciprocal concentric/eccentric tests. The spinal range of movement for the eccentric/concentric contractions was 60° (recorded from -20° extension, 0° neutral upright position to 40° of flexion) (Figure). A total of six alternating and continuous concentric/eccentric contractions was performed maximally. The alternating concentric/eccentric contractions required a minimum preload force of 50 Newtons and the dynamometer was set for a pause of 0.25 seconds between repetitions. The angular velocity was preset at 30°/sec (0.5236 rad/sec), partly to generate the highest possible peak torque and also for safety reasons.

Specific instructions were given to the subject to contract as hard and as fast as possible and standardized verbal encouragement was given to maximize the voluntary effort from the subject.

The flexor and extensor torques were compensated for the effects of gravity (2, 6, 12, 13). Prior to flexor testing, the gravity compensated torque was determined with the subject resting the trunk on the lever arm at an angle of 40° (flexion). This torque reading was used to determine the gravity-compensated torque. This procedure was repeated for extensor testing at an angle of -20° (extension).

Data Analysis

Means (±SD) were computed for all peak torque, angle at peak torque, peak torque relative to body mass, and anthropometric variables. The data were analyzed using analysis of variance (ANOVA) to test for concentric and eccentric flexor and extensor peak torque, angle at peak torque, and anthropometric differences between the four groups. The absolute peak torque data for both contraction types of the flexors and extensors were also standardized relative to body mass. This was accomplished by dividing the peak torque in Nm by the subject’s body mass in kg, and this variable was similarly analyzed by ANOVA. The level of significance of \( p \leq 0.05 \) was selected and a Scheffe post hoc test was used where appropriate.

RESULTS

Subjects

Anthropometric data presented in Table 1 revealed significant differences for height, body mass, and chest circumference of football players compared with the three other groups (\( p \leq 0.05 \)).

Isokinetic Concentric and Eccentric Flexor Torque

Table 2 shows the mean peak torque of the flexors for concentric and eccentric contractions. The rank order of mean peak torque for concentric and eccentric contractions was football players, soccer players, recreationally active subjects, and runners. A one-way ANOVA revealed significant differences between peak concentric and eccentric flexor torque. Scheffe post hoc analysis revealed a significant difference between football players, runners, and recreationally active subjects for both concentric and eccentric contractions (\( p \leq 0.05 \)). Significant differences were also found between soccer players and runners for both contraction types (\( p \leq 0.05 \)). Peak torque data standardized by body mass revealed no significant differences between the groups for concentric flexor strength (\( p \geq 0.05 \)). However, there were significant differences between

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Height (m)</th>
<th>Body Mass (kg)</th>
<th>Chest Circumference (cm)</th>
<th>Waist Circumference (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X SD</td>
<td>X SD</td>
<td>X SD</td>
<td>X SD</td>
</tr>
<tr>
<td>Soccer (N=16)</td>
<td>23.3 ± 2.4</td>
<td>1.77 ± 0.1</td>
<td>77.9 ± 6.3</td>
<td>99.5 ± 4.4</td>
</tr>
<tr>
<td>Football (N=15)</td>
<td>22.9 ± 2.3</td>
<td>1.83* ± 0.5</td>
<td>96.1** ± 15.0</td>
<td>109.9** ± 9.8</td>
</tr>
<tr>
<td>Runners (N=15)</td>
<td>23.2 ± 3.0</td>
<td>1.79 ± 0.6</td>
<td>75.3 ± 7.6</td>
<td>98.1 ± 5.0</td>
</tr>
<tr>
<td>Recreation (N=15)</td>
<td>22.1 ± 1.9</td>
<td>1.76 ± 0.6</td>
<td>75.4 ± 7.8</td>
<td>99.0 ± 5.6</td>
</tr>
</tbody>
</table>

* Significantly different from soccer players.
** Significantly different from runners.
*** Significantly different from recreationally active group.

TABLE 1. Anthropometric subject data (X ± SD) of the four groups.
Concentric flexors

<table>
<thead>
<tr>
<th></th>
<th>PT (Nm)</th>
<th>PTBM (Nm kg⁻¹)</th>
<th>APT (degrees)</th>
<th>PT (Nm)</th>
<th>PTBM (Nm kg⁻¹)</th>
<th>APT (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soccer (N=16)</td>
<td>211.6*</td>
<td>50.7</td>
<td>2.73</td>
<td>-16.0</td>
<td>1.1</td>
<td>-</td>
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<tr>
<td>Football (N=15)</td>
<td>236.1*</td>
<td>57.8</td>
<td>2.5</td>
<td>-13.3</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>Runners (N=15)</td>
<td>156.2</td>
<td>38.3</td>
<td>2.1</td>
<td>-17.8</td>
<td>0.9</td>
<td>-</td>
</tr>
<tr>
<td>Recreation (N=15)</td>
<td>169.1</td>
<td>50.4</td>
<td>2.3</td>
<td>-15.3</td>
<td>2.4</td>
<td>-</td>
</tr>
</tbody>
</table>

Eccentric flexors

<table>
<thead>
<tr>
<th></th>
<th>PT (Nm)</th>
<th>PTBM (Nm kg⁻¹)</th>
<th>APT (degrees)</th>
<th>PT (Nm)</th>
<th>PTBM (Nm kg⁻¹)</th>
<th>APT (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soccer (N=16)</td>
<td>234.6*</td>
<td>64.9</td>
<td>3.0*</td>
<td>3.0*</td>
<td>13.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Football (N=15)</td>
<td>258.8*</td>
<td>52.4</td>
<td>2.7</td>
<td>2.7</td>
<td>8.1</td>
<td>2.2</td>
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<tr>
<td>Runners (N=15)</td>
<td>174.5</td>
<td>37.6</td>
<td>2.4</td>
<td>2.4</td>
<td>13.6</td>
<td>2.1</td>
</tr>
<tr>
<td>Recreation (N=15)</td>
<td>179.3</td>
<td>58.5</td>
<td>2.4</td>
<td>2.4</td>
<td>11.4</td>
<td>3.0</td>
</tr>
</tbody>
</table>

* Significantly different from runners.

** Significantly different from recreationally active group.

PT = Peak torque.

PTBM = Peak torque relative to body mass.

APT = Angle at peak torque.

TABLE 2. Mean (± SD) value for absolute (Nm) and relative (Nm kg⁻¹) peak torque and angle at peak torque for concentric and eccentric flexors of the four groups through 60° range of motion.

the soccer players with runners and recreation subjects for eccentric flexor strength (p<0.05). There were no significant differences found between the groups for the angle at peak torque (p<0.05).

Isokinetic Concentric and Eccentric Extensor Torque

Table 3 shows the mean peak extensor torque for concentric and eccentric contractions. The rank order of peak torque for concentric contractions was football players followed by soccer players, recreationally active subjects, and runners. A one-way ANOVA revealed significant differences for peak concentric and eccentric extensor torque. Post hoc analysis showed significant differences between football players and runners (p<0.05). Peak torque relative to body mass for concentric or eccentric extensor strength revealed no significant differences between any of the groups (p>0.05). No significant differences were found between the groups for angle at peak torque (p<0.05).

DISCUSSION

Although direct comparisons are difficult to make because of differences in protocol and equipment, normative data are useful for athletic profiling. Intersport differences have been determined for female runners (20), judo players and cyclists (10), gymnasts, soccer, and tennis players (1), high school football players (7), and ballet dancers (4). The data from the present study showed that the football players had greater values for concentric flexor torque compared with the running and recreationally active groups. The values obtained by the soccer players for concentric flexion were significantly higher than those of the runners. The eccentric flexor peak torque revealed similar values for the football and soccer players, while
runners were not significantly different in peak torque than the recreationally active group. Surprisingly, soccer players' peak flexion torque was very similar to those of football players, despite being smaller in body size, and, when related to body mass, soccer players were significantly different than runners and recreationally active subjects. Although part of the soccer training program is geared to abdominal work, more sports-specific movement may account for the relatively high flexion torque. A major component of the performance of soccer involves the twisting and turning of the torso region, and the control of the trunk is of critical importance if stability is to be maintained as a player accelerates or decelerates (1). These findings of significant flexor trunk strength between the athletic groups, even when the data were normalized for body mass, are contradictory to Soldati et al (16), who found no significant differences in athletic groups. A possible explanation of the lower strength scores obtained by the runners who were all track athletes could be due to a dependence on trunk muscle endurance rather than muscular strength in order to control the trunk during running events.

The significant finding of higher absolute extensor torque between football players and runners concurs with some of the preliminary data from Soldati et al's (1) study of athletes who engaged in large volumes of weight training. In absolute terms, it is important for the football players to develop high levels of physical strength. This is reflected in the training program of the football team. The majority of the players have an individualized weight training schedule with a heavy emphasis on the upper body muscle groups. At the time of testing, football and soccer players were in the off-season developing their muscular strength and endurance; hence, this may partly explain the higher torque values. Also for the football players, it was not possible just to test one specific playing position and, hence, there was a wide range of torque scores because of the inclusion of linebackers, receivers, and quarterbacks, all positions which demand differing levels of strength. If the principles of specificity of training are observed, the overall volume of endurance training performed by the runners could account for the relatively low trunk scores. The runners were in the competitive phase of the season, concentrating on running as the basis for training. For the running group, low extensor torque values have been investigated as an association with low back pain, and whether the low values observed in runners are possible precursors to the onset of back problems is an intriguing question. If the recreationally active group are considered to be a norm reference group for student males of comparable age, the question of whether there is a training or sport-specific effect for running needs to be investigated. In addition, the selection of such an active recreation group, for comparative purposes, rather than a sedentary group may have resulted in higher torque scores. However, when the extensor data were expressed relative to body mass, there were no significant differences between the groups; therefore, the influence of body size should be considered when interpreting data between groups.

In contrast to the results of Anderssen et al (1), this study did not support the findings that athletes were able to attain peak flexion or extension torque sooner in the range of motion than normal subjects. Anderssen et al (1) postulated that athletes, through more effective recruitment of motor neurons, would be quicker to activate a maximal effort. A possible reason for the lack of a significant difference in angle at peak torque is due to the slow isokinetic velocity, and, if higher velocities were examined, significant differences might have emerged. Although it is accepted that 30°/sec is not indicative of the movements in competitive sport, it is not possible for an isokinetic instrument to mimic the true speeds generated by athletes, and, as the purpose was to determine the highest peak torque, a slow velocity was chosen. Indeed, when testing at higher isokinetic trunk velocities, the possibility of injury may be increased.

**CONCLUSION**

In conclusion, this study provides useful reference data of trunkal strength applicable to varsity athletes in sports which involve trunk movements in conjunction with the limbs. These results show that football and soccer players were stronger for flexor trunk strength than the running and recreation groups. Trunk extensor strength, however, did not show as large a group difference as the trunk flexors. Football players were significantly higher in peak extensor torque than runners. Relative peak torque values showed only soccer players to be significantly different in eccentric flexor strength compared with the running and recre-
RESEARCH STUDY

The results of this study can help in the evaluation of strength and its relative importance to a sport as well as highlighting the influence of body mass on the interpretation of peak torque values.

ACKNOWLEDGMENT

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REFERENCES

5. Canadian Standardised Test of Fitness. Operations Manual (3rd Ed), Minister of State Fitness and Amateur Sport, FAS 7378, 1986