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Research article

ANALYSIS OF ISOKINETIC KNEE EXTENSION / FLEXION IN MALE ELITE ADOLESCENT WRESTLERS

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ABSTRACT

Wrestling requires strength of the upper and lower body musculature which is critical for the athletic performance. Evaluation of the adolescent's skeletal muscle is important to understand body movement, especially including those involved in sports. Strength, power and endurance capacity are defined as parameters of skeletal muscle biomechanical properties. The isokinetic dynamometer is an important toll for making this type of evaluation. However, load range phase of range of motion has to be considered to interpret the data correctly. With this in mind we aimed to investigate the lover body musculature contractile characteristics of adolescent wrestlers together with detailed analyses of load range phase of motion. Thirteen boys aged 12 - 14 years participated to this study. Concentric load range torque, work and power of knee extension and flexion were measured by a Cybex Norm dynamometer at angular velocities from 450°/sec to 30°/sec with 30°/sec decrements for each set. None of the wrestlers were able to attain load range for angular velocities above 390°/sec and 420°/sec for extension and flexion respectively. Detailed analyses of the load range resulted in statistically significant differences in the normalized load range peak torque for extension at 270°/sec (1.44 ± 0.28 $Nm \cdot kg^{-1}$ and 1.14 ± 0.28 $Nm \cdot kg^{-1}$ for total and load range peak torque respectively, $p < 0.05$), and for flexion at 300 °/sec (1.26 ± 0.28 $Nm \cdot kg^{-1}$ and 1.03 ± 0.23 $Nm \cdot kg^{-1}$ for total and load range peak torque respectively, $p < 0.05$), compared to total peak torque data. Similarly, the significant difference was found for the work values at 90°/sec (1.91 ± 0.23 $Nm \cdot kg^{-1}$ and 1.59 ± 0.24 $Nm \cdot kg^{-1}$ for total and load range work respectively for extension and 1.73 ± 0.21 $Nm \cdot kg^{-1}$ and 1.49 ± 0.19 $Nm \cdot kg^{-1}$ for total and load range work respectively for flexion, $p < 0.05$), and was evident at higher angular velocities ($p < 0.001$) for both extension and flexion. At extension, load range power values were significantly smaller than total power for all angular velocities except 150°/sec ($p < 0.05$ for 120 and 180°/sec, $p < 0.001$ for others). Finally, load range flexion power was found to be higher than total power with statistically significance ($p < 0.05$ for 60, 120, 150, 180, 210, 270 and 300°/sec, $p < 0.001$ for 240 °/sec). Extra caution is required for correct interpretation of load range data in terms of considering the load range during limb movement. Evaluation of muscle performance of these adolescent wrestlers at regular intervals may give us an opportunity to obtain a healthy maturation profile of these adolescent wrestlers.

KEY WORDS: Wrestling, adolescent, isokinetic dynamometer, muscle, load range.

INTRODUCTION

Wrestling is one of the most important and prestigious sports in Turkey and numerous specially designed training schools exist to train and educate talented young wrestlers. The main goal of these organizations is to build up a group of wrestlers who are internationally competitive. Scientific evaluations of physical capacity, preparation of training schedule together with healthy maturation are critically important for improving the performance of these athletes.

Strength is essential in modern wrestling and wrestling falls in the category of sports defined as “strength–dependent” by Wrigley (2000). Wrestling events performed in a tournament setting and thus require multiple matches within a single day and on successive days. Therefore, wrestling tournaments present various physiological stresses (Horswill, 1992; Morgan, 1970). Because a wrestling match requires strength of the upper and lower body musculature for various wrestling techniques, evaluation of these variables may be important to determine athletic performance capacity (Horswill, 1992).

Knowing about the biochemical properties of an individual’s skeletal muscle is important to understand body movement, including those involved in sports and resistance exercise (Horman, 2000). Biomechanical studies are focused on the mechanisms through which the interacting body parts create movement. Strength, power and endurance capacity are defined important quantities among biomechanical properties. With the introduction of isokinetic dynamometer by Hislop and Perrine (1967), it has been possible to obtain objective and standardized measurements of strength produced by intact human muscle during different velocities of muscle shortening (Davies, et al., 2000; Thorstensson et al., 1976). Beside that measurements performed with dynamometer allows to study fiber type properties in the contraction muscle (Coyle et al., 1979; Gür et al., 2003). Since correlation between strength and athletic performance was demonstrated for strength-dependent sports, evaluation of muscle performance using the isokinetic dynamometer appears to be significant (Wrigley, 2000).

Isokinetic exercise involves three phases of movement; acceleration, constant velocity and deceleration (Brown and Whitehurst, 2000). The acceleration phase, rate of velocity development, represents the beginning part of the motion and is performed without resistance (Brown et al, 2005). Constant velocity phase follows the acceleration phase of movement and corresponds to the matching between mechanically imposed velocity and subject’s movement. By definition, the constant velocity portion of range of motion (ROM) represents load range. The third phase of motion, deceleration phase represents slowing down of the device prior to contacting the end stop (Brown and Whitehurst, 2000). Increased angular velocity results in a reduction in load range, thus data from the measurements that were performed at high angular velocities may not reflect load range values. From the classical force - velocity curve, there is an inverse exponential relationship between skeletal muscle contraction velocity and torque production (Widrick et al., 1996), and extra caution is required to make correct interpretation (Brown and Whitehurst, 2000).

With this in mind, we aimed to investigate: 1) The lower body musculature contractile characteristics of adolescent wrestlers by performing concentric extension and flexion of knee at different angular velocities, 2) evaluate the load range data by separating the load range phase from the acceleration and deceleration phases.

METHODS

Thirteen boys, competitive wrestlers between the ages of 12 and 14, participated in this study. They trained regularly about 12 hours per week throughout the year, under a common training program. The subjects avoided any systematic strength training two days before the testing day and none declared musculoskeletal problems. All athletes were accompanied by their coaches who gave their consent before engaging in the investigation.

Body weight and height were measured with standard techniques. Skinfold thickness at sites of abdomen (ABD), triceps (TSF), subscapular (SSF) and suprailiac (HSF) were measured on the right side of the body using a Holtain caliper (Holtain Ltd, Crymych, UK) and for each subject; the average of two measurements was recorded. Percentage of body fat (%BF) was estimated using the equation of Yuhasz (Wilmore and Benhke, 1969). The subjects’ lean body mass (LBM) was calculated by subtracting fat tissue from the total body mass (Mameletzi and Siatras, 2003).

Concentric peak torque was measured using a Cybex Norm dynamometer (Computerized Sports Medicine Inc. USA). Subjects were seated for testing in the dynamometer’s chair with the backrest angle at 90°. The axis of rotation of the right knee was aligned with the axis of rotation of the dynamometer’s armature and the ankle cuff was attached approximately 3 cm above the dorsal surface of the foot. Gravity correction was performed throughout the testing duration. Stabilization straps were placed over the pelvis and chest, and participants positioned their arms across their chests during the familiarization and testing. Immediately before familiarization a standard

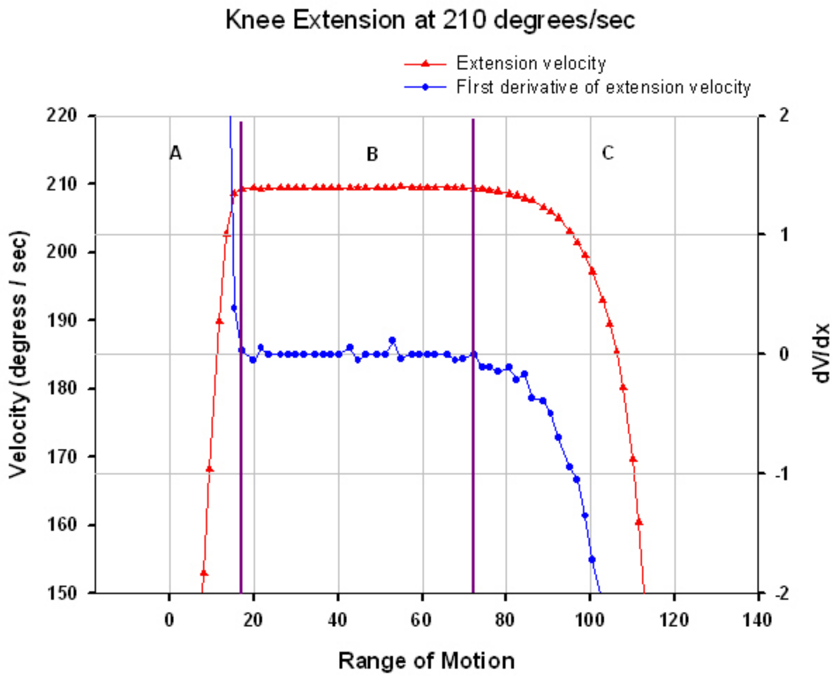


Figure 1. Example to the first derivative of ROM – velocity curve that used to calculate load range phase of angular movement of 210°/sec knee extension. A: Deceleration phase. B: Load range phase. C: Rate of velocity development phase. Values are means ± SD.

cycling warm-up protocol was performed (Parcell et al., 2002). Subjects exercised on a cycle ergometer for 5 min with 55 ± 5 rpm. The load was adjusted according to the subject's heart beats. Heart beats were recorded continuously with a telemetric heart rate monitor (S810, Polar, Finland). During the cycling the subject's heart beats were kept between 100 - 120 beats·min^{-1}. For familiarization with isokinetic contraction velocities, subjects performed four maximal repetitions at 90, 240 and 390°/sec with 1-min rest between sets. For all testing sessions, subjects performed maximal isokinetic contractions with a protocol from fast to slow velocity (from 450°/sec to 30°/sec with 30°/sec decrements) with 3 repetitions. Although most investigators are administered these velocities in ascending order (Parcell, 2002), subjects of this study verbally confirmed the convenience for descending order. The range of motion for the contractions was performed from full extension (0 degree) to full flexion (103.63 ± 6.37 degrees). Subjects began each set with maximal flexion. They were instructed to contract maximally over the complete range of motion and rested for 1 minute between each set. During testing session the subjects were given verbal encouragement to help to ensure that a maximal effort was being put forth.

The torque, range of motion and velocity data was used for calculations. The data collected directly from the dynamometer and no accessory equipment used to increase the sampling frequency. Among the three repetitions, the one that had the highest torque was accepted and calculations were performed in this data set. The calculations mentioned below were performed for all velocities both for flexion and extension. Torque data were normalized with respect to body weight.

The range of motion – velocity graph was plotted and the acceleration was calculated by taking the first derivative of velocity with respect to range of motion as shown in Figure 1. The data points near to zero value (fluctuations equal to 0 ± 0.2) in the first derivative curve were accepted as isokinetic (load range). The ratio of load range to total range of motion was defined as load range percentage of motion and used to calculate load range peak torque, work and power.

Total work done during both extension and flexion was calculated by integrating the range of motion - torque graph. The area below the total plot is the work done during the range of motion. Load range work was calculated from the isokinetic range of motion - torque graph as well.

Peak torque and the joint angle at peak torque were determined for both flexion and extension of total and load range of motions. The flexion – extension (F/E) ratio was calculated for both peak toque and power values.

Load range – peak torque ratio for 240°/sec : 30°/sec torque ratio was used to predict muscle fiber type distribution as described by Gür et al. (2003).

Statistics

Values were expressed as mean ± SD. Repeated measures analyses was used to analyze the data within and between groups. Student t-test was used to compare the difference between groups at each angular velocity. Paired t test was used within groups to compare the baseline data (at 30°/sec) with each angular velocity. Significance was defined as $p < 0.05$.

RESULTS

The descriptive characteristics of the young wrestlers aged 12 - 14 are presented in Table 1.

Table 1. Age, physical (height and weight) and anthropometrical characteristics (skinfolds, body fat and lean body mass) of subjects (n = 13). Values are means (±SD).

Age (years)	12.9 (.5)
Height (m)	1.53 (.10)
Weight (kg)	44.8 (9.2)
ABD (mm)	7.85 (3.02)
TSF (mm)	7.79 (2.14)
SSF (mm)	5.98 (1.13)
HSF (mm)	6.93 (2.48)
BF (%)	10.15 (1.27)
LBM (kg)	40.16 (7.92)

ABD = Abdomen skinfold, TSF = Triceps skinfold, SSF = Scapula skinfold, HSF = Suprailiac skinfold, BF = Body fat, LBM = Lean body mass.

The load range percent of the total ROM for extension and flexion at increasing angular velocities are represented in Figure 2A and 2B respectively. Increased angular velocity resulted in a reduction in the load range percentage from 94.02 ± 0.71 % (30°/sec) to 4.12 ± 1.83 % (390°/sec) for extension and from 94.50 ± 0.73 % (30°/sec) to 6.56 ± 1.48 % (420°/sec) for flexion. The subjects could not attain the load range at higher velocities above 390°/sec for extension and 420°/sec for flexion.

The measured load range peak torque joint angles for extension decreased from 89.95° ± 10.45 to 38.81° ± 1.17 for 30°/sec to 390°/sec respectively (Figure 3). Similarly peak torque joint angles increased for flexion from 23.41° ± 8.11 to 72.83° ± 1.09 for 30°/sec to 420°/sec respectively (Figure 3). These data is in agreement with the values that Osternig (2000) presented.

Normalized peak torque values for the total contraction and the load range phase at different angular velocities for extension and flexion are given in Figure 4A and B respectively. In Figure 4A peak torque decreased in both total contraction and load range phases at higher angular velocities. At 30°/sec and 60°/sec angular velocities, peak torques of total contraction and load range phases are identical (p = 1.00). At increased angular velocities, an insignificant change occurred and became statistically significant above 270°/sec (1.44 ± 0.28 $Nm \cdot kg^{-1}$ body weight for total peak torque and 1.14 ± 0.28 $Nm \cdot kg^{-1}$ body weight for load range peak torque; $p < 0.05$). A similar relationship was observed in the flexion part of the motion. For 30°/sec, 60°/sec, 90°/sec and 120°/sec velocities, peak torques of total contraction and load range phases were identical as well (p = 1.00). This similarity began to change at velocities higher than 120°/sec and statistically significant difference was observed above 300°/sec (1.26 ± 0.28 $Nm \cdot kg^{-1}$ body weight for total peak torque and 1.03 ± 0.23 $Nm \cdot kg^{-1}$ body weight for load range peak torque; $p < 0.05$).

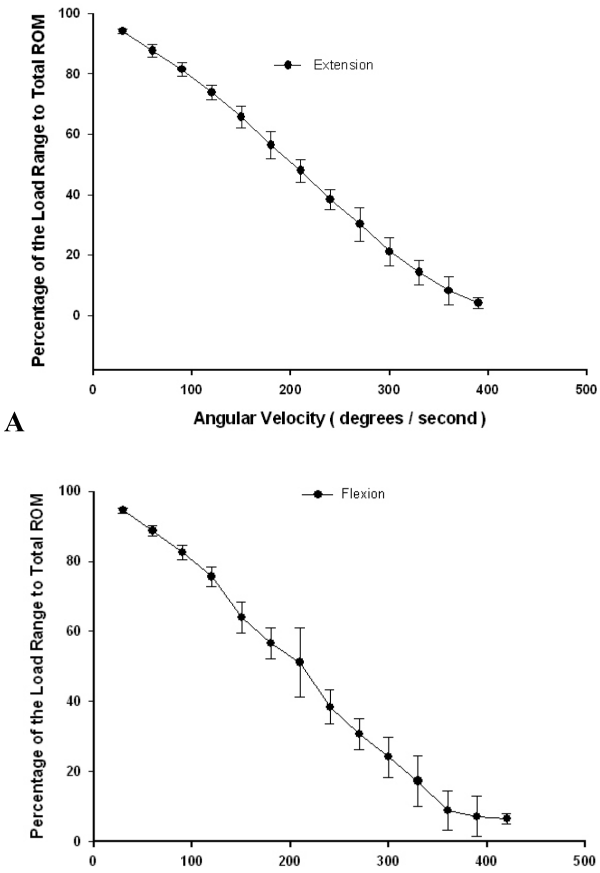


Figure 2. Load range percent of the total range of motion at different angular velocities. A: Extension. B: Flexion. ROM: Range of Motion. Values are means ± SD.

Normalized load range peak torque ratio of 240°/sec : 30°/sec was calculated as 0.47 ± 0.06. This value corresponds to nearly 30% of relative type II fiber area (Gür et al., 2003).

Calculated normalized work values ($Nm \cdot kg^{-1}$ body weight) for different angular velocities are given in Figure 5A and 5B for extension and flexion respectively. Total and load range work values decreased at higher angular velocities and showed similar reduction pattern for extension and flexion.

For extension phase calculated load range work is statistically different than the total work in angular velocities above 90°/sec (1.91 ± 0.23 for total normalized work and 1.59 ± 0.24 for load range normalized work; $p < 0.05$). In the flexion phase the statistically significant difference between total and calculated load range work was determined at 90°/sec as well (1.73 ± 0.21 for total normalized work and 1.49 ± 0.19 for load range normalized work; $p < 0.05$). The difference for the angular velocities above 90°/sec was also significant ($p < 0.001$).

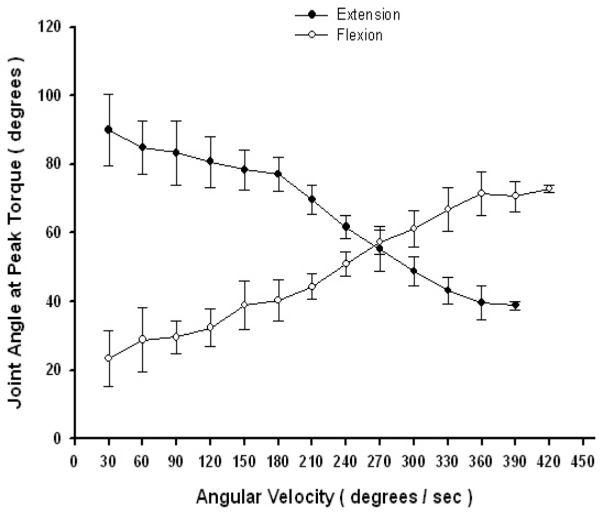


Figure 3. Joint angle at the peak torque with changes in angular velocities. Values are means ± SD.

The extension and flexion data of the power – angular velocity plots are presented in Figure 6A and 6B respectively. As shown in Figure 6A, both total and load range power (Watt·kg^{-1} body weight) reached peak values 210°/sec (2.6 ± 0.41 for load range power and 3.27 ± 0.31 for total power). On the other hand, at higher angular velocities load range power values decreased to 1.13 ± 0.38 at 390°/sec, whereas total power was calculated as 3.17 ± 0.44. The differences between total and load range power for angular velocities from 30°/sec to 390°/sec are statistically significant except at 150°/sec ($p < 0.05$ for 120 - 180°/sec and $p<0.001$ for rest of the angular velocities). In the flexion part of the motion the calculated load range power values were significantly higher than total power values between 60 - 300°/sec except at 90°/sec ($p < 0.001$ for 240°/sec and $p < 0.05$ for the rest of the angular velocities).

Peak torque flexion - extension ratio (F/E) is presented in Figure 7. The ratio increased significantly after 180°/sec (0.81 ± 0.08). There was also a significant difference between 30°/sec and 120°/sec (0.71 ± 0.06 and 0.80 ± 0.08 respectively).

Similarly, F/E for muscle power is increased significantly beginning at 120°/sec (0.93 ± 0.15) compared to 30°/sec (0.87 ± 0.09) (Figure 8).

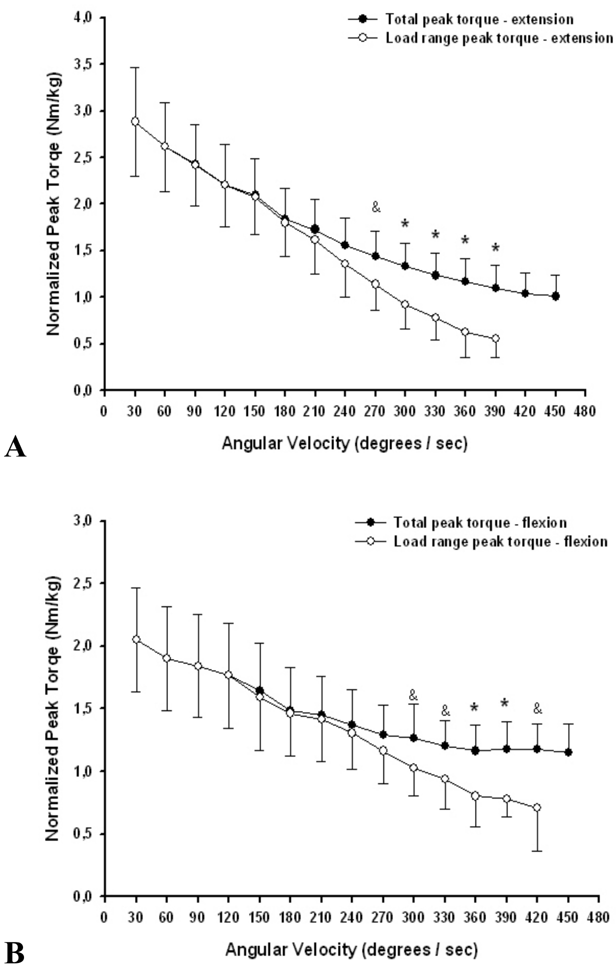
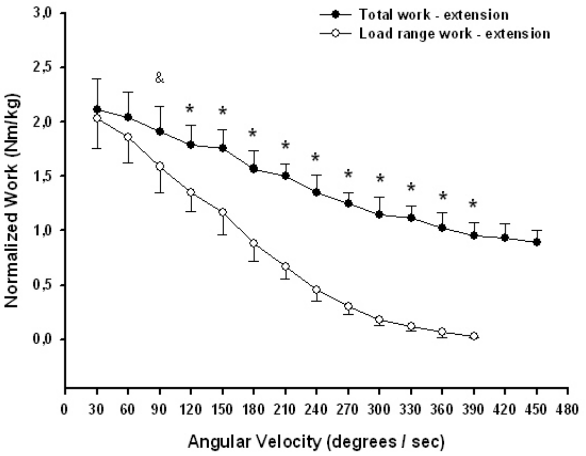


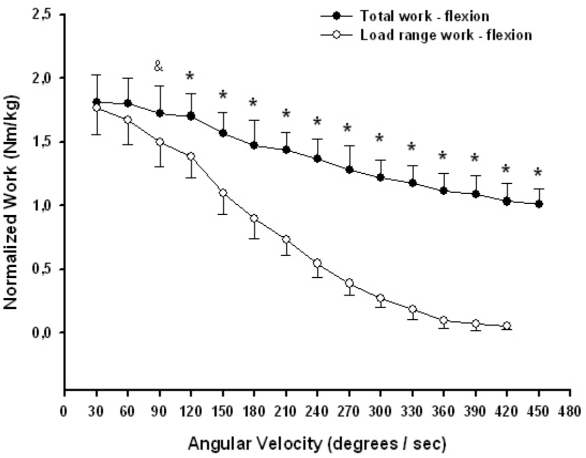
Figure 4. Normalized total and load range peak torque – angular velocities. A: Extension. B: Flexion. Values are means ± SD. & and * indicate $p < 0.05$ and 0.001, respectively, from corresponding angular velocity of load range normalized peak torque value.

DISCUSSION

The results of our study support the argument that load range is reduced with increased angular speed of knee extension and flexion. Adolescent wrestlers could not reach the load range phase of motion over the angular velocities of 390°/sec for extension and 420°/sec for flexion. In fact isokinetic dynamometers provide an upper limit for angular velocity and it is a possibility for individuals to complete contractions without reaching predetermined velocity. Consideration of load range for peak torque, work and power calculation resulted significant differences in the data presented by isokinetic dynamometer. Since the athlete received an external load through the smaller portion of the full ROM as angular velocity of motion increased (Brown et al., 1995), it was necessary to take this into account in analyzing the data. As underlined by Brown and Whitehusrt (2000), to ignore this situation may cause incorrect interpretation of the load range data.



A

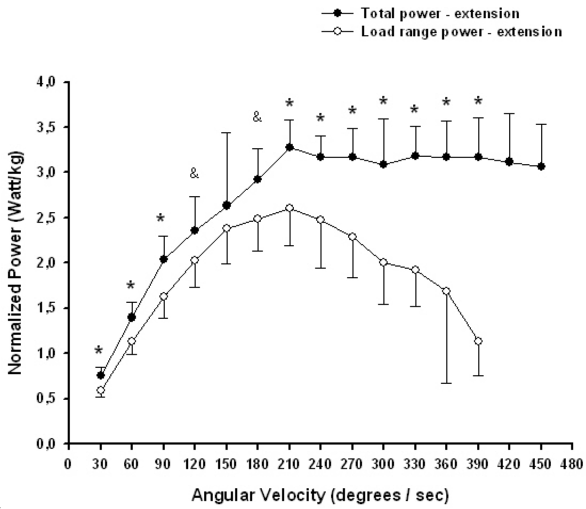


B

Figure 5. Normalized total and load range work – angular velocities. A: Extension. B: Flexion. Values are means ± SD. & and * indicate $p < 0.05$ and 0.001, respectively, from corresponding angular velocity of load range normalized work value.

Detection of the load range

Discrimination of acceleration and deceleration phases had been possible by using the derivative analyses of ROM - velocity curve for each angular velocity. As shown by Lanza et al (2003), constant velocity part of the angular velocity trace during knee extension and flexion represents the load range phase of the ROM. Plotting the derivative values of this curve made it possible to identify clearly the acceleration and deceleration phases. The middle portion of this curve was very close to zero (fluctuations 0 ± 0.2, Figure 1) and defined as the load range. By performing this mathematical evaluation for every individual data set, we claim that the detection of load range has been objective and accurate. At this point we do not have enough data to explain the very small differential fluctuations in the load range, but this may represent the instability between the lever arm and moving limb.



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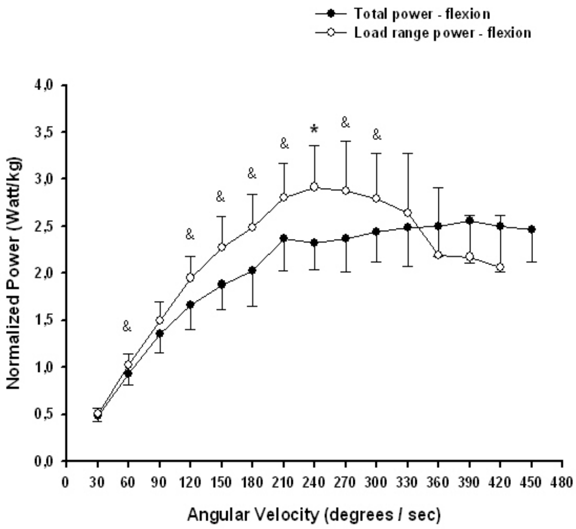

B

Figure 6. Normalized total and load range power – angular velocities. A: Extension. B: Flexion. Values are means ± SD. & and * indicate $p < 0.05$ and 0.001, respectively, from corresponding angular velocity of load range normalized power value.

Attaining load range

Decreased load range percentage of the ROM at increased angular velocities showed significant changes between the total and load range peak torque values at slow contraction velocities (Figure 4A and Figure 4B). However work (Figure 5A and Figure 5B) and power values (Figure 6A and Figure 6B) have also been significant at lower angular velocities. These data are in agreement with the data presented by Lanza et al (2003). Contraction velocity has critical importance in determining the load range attaining ability for a moving limb during load range evaluation. In fact alterations in contraction speed may be due to a number of changes in muscle morphology, subjects' age and the ratio between type I and type II muscle fiber area

(Larsson, 1995; Lexell and Downham, 1992; Thorstensson et al., 1976). The ability to generate high motor unit discharge rate is another important parameter affecting the changes in muscle contraction velocity (Connelly et al., 1999; Kamel et al., 1995). The presence of this multifactorial variability may explain the interindividual muscle contractility differences that we observed in our study.

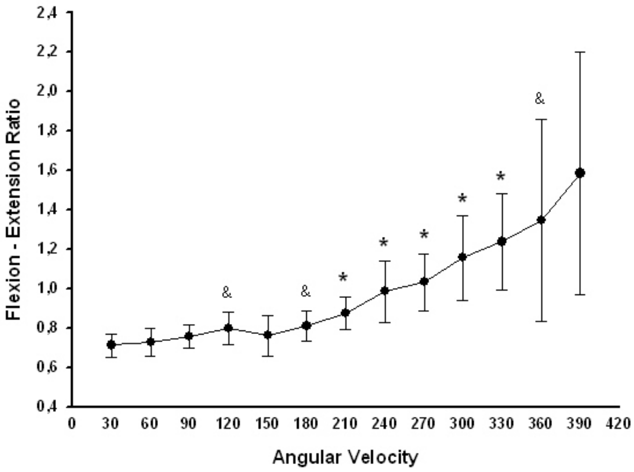

Figure 7. Knee flexion – extension ratios at different angular velocities of peak torque. Values are means ± SD. & and * indicate p < 0.05 and 0.001, respectively, * indicates significant difference compared to values at angular velocities 30, 60, 90 and 150°/sec (p < 0.001).

Evaluation of the athletic performance

Even though some data related to isokinetic evaluation of adolescent wrestlers have been published before, to the best of our knowledge no detailed studies of the subject have been previously reported. For a sport such as wrestling, muscle strength, power and velocity are the main determinants for success. Therefore percentage of type II fibers is an important determinant of athletic achievement. Detecting the differences in myosine isoform may be possible by performing dynamic contractions at different angular velocities with an isokinetic dynamometer (Gür et al., 2003). Considering the previously published regression equations by Gür et al (2003), we estimated the relative type II muscle fiber area of knee extensors as nearly 30%. However, the ratio that we calculated shows that subjects of this study had smaller portion of fast twitch muscle fibers. As reported previously, age may be an important factor for determination of isokinetic strength. The increase in strength with maturation, the age effect, may be attributed to increase in body size (Housh et al., 1996; Thorland et al., 1990), alterations in fat free mass, neuromuscular maturation (Malmstorm and Lindstrom, 1997) and changes in muscle tissue itself (Cooper et al., 1984; Welsman et al, 1996). It should be noted that Costill et al. (1979) observed a selective hypertrophy of fast twitch muscles with strength training. A child's performance and adaptation to training should not be directly compared to that of an adult as significant differences exist, especially during the accelerated growth with puberty (Bailey and Martin, 1988). It will be very important to evaluate changes in contractile properties during these wrestlers' maturation.

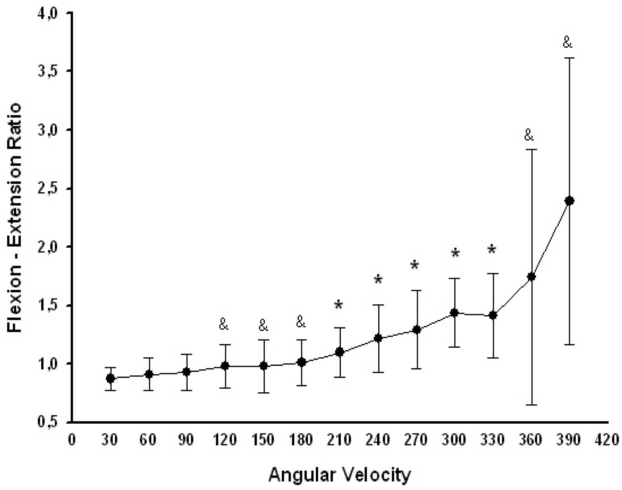

Figure 8. Knee flexion – extension ratios at different angular velocities of power. Values are means ± SD. * indicates significant difference compared to values at angular velocity of 30°/sec (p < 0.001). & indicates significant difference compared to values at angular velocities 30, 60, 90 and 150°/sec (p < 0.05).

The peak torque and power values in the present study are slightly higher than the adolescent with low level physical activity (Larsson et al., 1979). On the other hand peak torque values for extension and flexion together with flexion power data are in agreement with the data published by Mameletzi and Siatras (2003). However relative power values for knee extension were lower than the data presented by these investigators. Taking the load range into consideration may explain the disparity for knee extension. Since, prepubertal growth and bioenergetic characteristics of adolescent may not be dependent on regular athletic activity (Damsgaard et al., 2000), the values that we measured may reflect the genetic characteristics of the adolescent (Bailey and Martin, 1988). On the other hand, normalized peak torque values tended to be higher in Olympic level competitive wrestlers (Kraemer et al., 2001). Training history as well as differences in age groups may explain this disparity. Age is an important factor in determining torque, velocity and power characteristics of skeletal muscle

(Lanza et al, 2003) and dynamic strength reaches the peak values at the age group of (Larsson et al., 1979; Lindle, 1997) 20 – 30 years. Endocrinological changes with puberty, training history and related physiological alterations may explain the difference of load range contraction characteristics of our study, as compared to elite adult wrestlers.

Concerning the comparison of knee flexion and extension ratio (F/E), significant differences were observed at angular velocities over 180°/sec for peak torque, and 120°/sec for muscle power values. Weir et al. (1999) reported similar ratios for muscle peak torque in wrestlers in the same age group for the angular velocities at 30°/sec and 180°/sec. However previously reported F/E for peak torque ratio at 300°/sec was lower than the ratio presented in the present study. The disparity between these two studies for the high angular velocities may be due to the difference in isokinetic testing mode. On the other hand, F/E peak torque ratio was found to be higher than the adolescent swimmers studied by Mameletzi and Siatras (2003). By training in the aquatic environment, swimmers have to perform isokinetic exercise continuously (Åstrand and Rodahl, 1977). On the other hand wrestlers had to train against gravity. Difference in the physical training environment may explain the disparity between these two types of athletes. F/E ratio of peak torque and power may provide important information about knee joint stability. The calculated F/E ratio for the angular velocities above 120°/sec had shown a significantly differences compare to the values of 30°/sec. Explaining this imbalance for high angular velocities is not possible with the present data but may be interpreted as a risk factor for muscle injury occurrence.

CONCLUSIONS

Evaluation of the dynamometer data required consideration of the load range for correct analysis and interpretation. The presence of statistically significant differences at lower angular velocities demonstrates the importance of load range determination. The athletic performance of adolescent wrestlers is in agreement with the data published with different investigators. Repeating muscle performance evaluation in regular intervals may give us an opportunity to prepare the maturation profile of these adolescent wrestlers.

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KEY POINTS

- Consideration of load range for peak torque, work and power calculation resulted significant differences in the data presented by isokinetic dynamometer. Therefore evaluation of the dynamometer data required consideration of the load range for correct analysis and interpretation.
- Contraction velocity has critical importance in determining the load range attaining ability for a moving limb during load range evaluation. In fact alterations in contraction speed may be due to a number of changes in muscle morphology, subjects' age and the ratio between type I and type II muscle fiber area.

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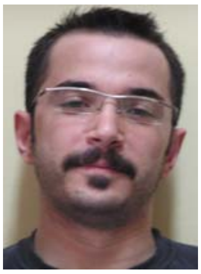

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