Fatigue resistance of thigh muscles in sport games players

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Abstract

Background and Study Aim. Changed thigh muscles action balance can cause sports injuries. The aim of our investigation was the knowledge about effect of thigh muscles fatigue resistance on the knee flexor (Fl)/extensor (Ext) muscles mean work (W) and power (P) ratio.

Material and Methods. Fourteen amateur male handball players participated. The tests were carried out by a dynamometer system using the knee isokinetic flexion–extension movements at angular velocity of 90°/s (five repetitions) and 240°/s (20 repetitions) by the concentric contractions. The mean thigh muscles W, P and Fl/Ext muscles mean W and P ratios were calculated for the first ten and last ten repetitions. The correlation between the thigh muscles peak torques (τmax) at the velocity of 90°/s, 240°/s and W, P at the first and last ten repetitions was determined.

Results. Mean W produced by the knee Fl in the last ten movements was smaller than in the first ten motions (p<0.02). The knee WFl/WExt=0.69; PFl/PExt=0.65 in the last ten motions were lower than in the first ten movements: WFl/WExt=0.73; PFl/PExt=0.71 (p<0.002). Therefore the knee joint trauma may occur more probably after fatigue appearance. The positive correlation between thigh muscles τmax and W, P in the first ten and last ten knee movements (p<0.01) confirms that strength training of muscles will improve not only the maximal strength but also the fatigue resistance.

Conclusion. The significant positive correlation between thigh (hamstrings and quadriceps femoris) muscles peak torques and the mean work and power of the same muscles in the first ten and last ten knee flexion–extension movements (p<0.01) confirms that the strength training of these muscle groups will improve not only the maximal strength but also the fatigue resistance of these muscles.

Key words: flexion–extension movement • handball • knee • strength and power balance

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INTRODUCTION

The influence of knee flexor (hamstrings) and extensor (quadriceps femoris) muscles fatigue resistance on knee muscles strength ratio during flexion–extension movements is not investigated in wide scale. Only few authors are investigated a relationship between the knee flexor and extensor muscles strength balance and an occurrence of injuries for healthy athletes. For example, Knapi et al. [1] revealed that the thigh muscles strength imbalance measured at fast velocity of movements by isokinetic dynamometer is associated with injuries. The predisposing factors to injury are [2]: changed muscles agonists/antagonists’s strength, work and power balance, lack of flexibility in the joint, insufficient warm-up before exercises and fatigue of muscles.

An investigation method of the thigh muscles strength (torques produced by the muscles agonists and antagonists) balance and the same muscles mean work and power balance is the isokinetic dynamometry. A mean value for the knee flexor/extensor (hamstrings/ quadriceps femoris) muscles peak torques ratio in concentric contraction of the muscles is approximately 60% at slow angular velocity of movement of 30°–60°/s [3-5]. The value of this ratio increases with the growth of the velocity of movements, and it is close to 80% at the fast velocity of 240°-300°/s [6-9]. Pontaga I. [10] determined that the mean knee flexor/ extensor muscles peak torques ratio of male students trained in sport and extensor muscles strength balance and an occurrence of injuries for healthy athletes. For example, Knapi et al. [1] revealed that the thigh muscles strength imbalance measured at fast velocity of movements by isokinetic dynamometer is associated with injuries. The predisposing factors to injury are [2]: changed muscles agonists/antagonists’s strength, work and power balance, lack of flexibility in the joint, insufficient warm-up before exercises and fatigue of muscles.

If the hamstrings muscles are too weak in comparison with the quadriceps femoris muscle, it can change the muscles action balance and to create additional mechanical stresses on the knee anterior cruciate ligament (ACL) [11]. These muscles partially compensate the knee ACL ligaments functions: they restrict the anterior movement of a tibia relative to a femur and provide resistance to valgus and varus deformations of the leg in the knee joint, as well as, to rotation of the tibia [2]. Therefore weakness of the hamstring muscles can promote the knee joint trauma occurrence in sport activities.

Isokinetic muscle endurance is the capacity of a muscle to perform work, and fatigue is measured as a decline in work production over a series of consecutive contractions [12]. Total work performed over several isokinetic contractions is a valid indicator of the endurance capacity of a single muscle group. Kannus [13] showed that the total work performed during a 25 repetition isokinetic test and the total work performed for the final five of the 25 repetitions were as significant and consistent as peak torque for the measurement of muscle endurance capacity.

The aim of our investigation was the knowledge about effect of thigh muscles fatigue resistance on the knee flexor/ extensor muscles mean work and power ratio.

MATERIALS AND METHODS

Participants

Fourteen amateur male athletes played in Premium league team were informed of possible test risks and voluntarily participated in the investigation. Their training experience in team handball ranged from seven to ten years. These athletes trained five times per week and played regularly on the weekends. The study was performed in accordance with the standards of the Ethics Committee of the Latvian Council of Sciences. All knee joints of the athletes were injury free and painless during the investigation. The mean age, body height, body mass and body mass index of the tested athletes equaled: 19±2 years, 187±5 cm, 79±7 kg and 22.52±1.51 kg/m².

Procedures

The tests were performed using the dynamometer system REV-9000 (Technogym, Gambettola, Italy) in the isokinetic knee flexion–extension movements at the medium angular velocity 90°/s (degrees per second) and high velocity 240°/s. The range of movements was from 10° in the knee extension to 90° in flexion. The person was placed in the positioning seat with the hip at an angle of 120° of flexion. The hip and trunk were fixed by stabilizing straps. The support lever was attached at the point between the upper two thirds and the lower third of the shin. The athlete was fixed in position after adjustment of the depth of the seat, the height of the dynamometer and the length of support lever to be aligned with a prolonged virtual rotation axis of the knee. The rotation axis of the knee joint was determined as a line passing through the femoral condyles. The measurements were corrected for the effects of gravity.

Passive internal–external rotation motions in the knee joint were performed for 90 s at an angular velocity of 120°/s just before the investigation. The athletes were given detailed verbal instructions of the procedures and performed five submaximal warm-up repetitions before the test.
The test began with the knee extension from 90° of the range of movements – extreme flexion position. The knee isokinetic concentric flexion–extension movements were tested at angular velocity values of 90°/s and 240°/s. The movements were repeated five times at the velocity of 90°/s and 20 times at the velocity of 240°/s. Subjects were verbally encouraged to maximally move the extremity “as hard and as fast as possible” during concentric testing. The passive flexion–extension motions in the knee joint were performed for 90 s at the angular velocity of 120°/s between tests of different velocities.

Peak torque ($\tau_{\text{max}}$) values (N·m) of the knee flexor and extensor muscles were obtained from the best repetition (greatest peak torque). The mean work (W) and mean power (P) of the knee flexor and extensor muscles of the both legs were determined for the first ten and last ten repetitions of knee flexion–extension movements at an angular velocity of 240°/s. The mean work and power ratios of the knee flexor/extensor muscles were calculated for the first ten and last ten repetitions of movements.

**Statistic**

Mean values and standard deviations for all characteristics were calculated. A dependent t-test for paired data groups was employed to determine differences between the mean W, mean P, and mean W and P ratios of the knee flexor/extensor muscles in the first ten and last ten repetitions of knee flexion–extension movements at the velocity of 240°/s. The differences were considered statistically significant at $p < 0.05$. The linear correlation analysis was used to determine the relationships between the peak torques of knee flexor and extensor muscles at both velocities (90°/s and 240°/s) and the mean work and power of the same muscles in the first ten and last ten repetitions of movements at the last angular velocity of 240°/s. Microsoft Excel 2007 was used to perform all statistical procedures.

### RESULTS

The mean work and power of the knee extensor muscles in the first ten and last ten flexion – extension movements did not differ significantly (Table 1). The mean power of knee flexor muscles in the first ten and last ten movements did not differ significantly. The mean work of knee flexor muscles in the last ten movement repetitions was significantly smaller than in the first ten movements ($p < 0.02$).

#### Table 1. The mean work (W) and power (P) of knee extensor (Ext) and flexor (Fl) muscles in the first ten and last ten repetitions of the knee flexion – extension movements at the velocity of 240°/s

<table>
<thead>
<tr>
<th>Repetitions</th>
<th>First ten</th>
<th>Last ten</th>
<th>Sign. of difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{\text{ext}}$ (J)</td>
<td>127 ± 19</td>
<td>128 ± 17</td>
<td>$p &gt; 0.05$</td>
</tr>
<tr>
<td>$P_{\text{ext}}$ (W)</td>
<td>235 ± 47</td>
<td>240 ± 36</td>
<td>$p &gt; 0.05$</td>
</tr>
<tr>
<td>$W_{\text{fl}}$ (J)</td>
<td>92 ± 11</td>
<td>88 ± 9</td>
<td>$p = 0.02$</td>
</tr>
<tr>
<td>$P_{\text{fl}}$ (W)</td>
<td>161 ± 31</td>
<td>156 ± 24</td>
<td>$p &gt; 0.05$</td>
</tr>
</tbody>
</table>

The knee flexor/extensor muscles mean work and power ratios were lower in the last ten movements in comparison with the first ten, $p < 0.002$ (Table 2).

#### Table 2. The mean work (W) and mean power (P) ratio values of knee Fl/Ext muscles in the first ten and last ten repetitions of the knee flexion – extension movements at the velocity of 240°/s

<table>
<thead>
<tr>
<th>Repetitions</th>
<th>First ten</th>
<th>Last ten</th>
<th>Sign. of diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{\text{fl}}/W_{\text{ext}}$</td>
<td>0.73 ± 0.11</td>
<td>0.69 ± 0.10</td>
<td>$p = 0.002$</td>
</tr>
<tr>
<td>$P_{\text{fl}}/P_{\text{ext}}$</td>
<td>0.71 ± 0.11</td>
<td>0.65 ± 0.09</td>
<td>$p = 0.001$</td>
</tr>
</tbody>
</table>

Positive significant correlations were determined between the $\tau_{\text{max}}$ and mean W or P of the knee flexor and extensor muscles developed by the same muscles in the first ten and last ten repetitions of knee flexion–extension movements at the angular velocity of 240°/s (correlation coefficients varied from 0.49 to 0.81, $p < 0.01$) (Table 3).

#### Table 3. The correlation coefficients between the peak torque ($\tau_{\text{max}}$) and mean work or power of knee extensor (Ext) and flexor (Fl) muscles developed by the same muscles in the first ten and last ten repetitions of knee flexion – extension movements at the velocity of 240°/s ($p < 0.01$)

<table>
<thead>
<tr>
<th>Velocity of movement</th>
<th>Peak torque</th>
<th>Mean</th>
<th>Work (J)</th>
<th>Mean</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>First 10 repetitions</td>
<td>Last 10 repetitions</td>
<td>First 10 repetitions</td>
<td>Last 10 repetitions</td>
</tr>
<tr>
<td>90°/s</td>
<td>$\tau_{\text{max}}$ (ext)</td>
<td>0.65</td>
<td>0.56</td>
<td>0.65</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>$\tau_{\text{max}}$ (fl)</td>
<td>0.62</td>
<td>0.62</td>
<td>0.59</td>
<td>0.47</td>
</tr>
<tr>
<td>240°/s</td>
<td>$\tau_{\text{max}}$ (ext)</td>
<td>0.49</td>
<td>0.63</td>
<td>0.76</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>$\tau_{\text{max}}$ (fl)</td>
<td>0.49</td>
<td>0.55</td>
<td>0.62</td>
<td>0.67</td>
</tr>
</tbody>
</table>
The correlation coefficients between $\tau_{\text{max}}$ of the knee muscles measured at the medium (90°/s) or fast (240°/s) angular velocity and mean work of the same muscles was similar ($r$ varied from 0.49 to 0.65). The correlation coefficients between $\tau_{\text{max}}$ of the knee muscles at the angular velocity of 240°/s and mean power of the same muscles were closer ($r$ varied from 0.62 to 0.81) in comparison with the correlations between the $\tau_{\text{max}}$ of these muscles measured at the angular velocity of 90°/s and mean power produced by the muscles ($r$ varied from 0.47 to 0.65).

**DISCUSSION**

From our data training in team handball causes better strength and fatigue resistance development in the knee extensor muscles (quadriceps femoris) in comparison with the knee flexors (hamstrings) in many players. Fatigue of the knee flexor muscles appears faster than of the extensor muscles because the mean work produced by the knee flexors in the last ten flexion – extension movement repetitions was significantly smaller than in the first ten motions ($p<0.02$). This causes significant decrease of the knee flexor/ extensor muscles mean work and power ratios in the last ten motions ($W_{\text{fl}}/W_{\text{ext}} = 0.69; P_{\text{fl}}/P_{\text{ext}} = 0.65$) in comparison with the first ten knee flexion–extension movements ($W_{\text{fl}}/W_{\text{ext}} = 0.73; P_{\text{fl}}/P_{\text{ext}} = 0.71$), $p<0.002$. Due to the hamstrings muscles lower fatigue resistance and relative weakness in work and power production in comparison with the quadriceps femoris muscle after many repetitions of the knee flexion-extension movements, the thigh muscles action balance is changed, additional mechanical stresses on the knee anterior cruciate ligament (ACL) are created and this can be a reason of the injury of ACL [11]. Therefore the knee joint trauma may occur more probably after many knee flexion-extension movement repetitions or in the end of the game or training in handball players.

The hypertrophy of hamstrings can appear as a compensatory reaction to knee injuries. For example, the greater knee flexor/ extensor peak torques ratio (60-70%) is observed in the operated leg of male sport games players six to 13 months after the knee ACL reconstructive operation in comparison with the contralateral legs’ muscles ratios without special training exercises of hamstrings [14], as well as, in comparison with the average ratio value of uninjured people 61% ±7% in the concentric/ concentric contractions of the thigh muscles [10]. This can be explained by the quadriceps femoris muscle relative weakness and the hamstrings hypertrophy to compensate partially the ACL functions to restrict the anterior movement and rotation of the tibia in the operated leg.

One commonly held belief is that muscle hypertrophy induces increased strength at the expense of fatigue resistance or strength endurance, which is not confirmed by research data [15]. Rube and Secher [16] determined that a five-week program of static training using maximal isometric knee extensions increased fatigue resistance as tested by maximal extensions every fifth second. When the test was performed bilaterally, improvements were observed only in groups that had trained bilaterally, but improvement in unilateral fatigue was evident only in the group that had trained unilaterally with that leg. This investigation supports the positive effect of static strength training on fatigue resistance. These results agree with our data that the increase in the $\tau_{\text{max}}$ values of the knee flexor and extensor muscles at medium (90°/s) and fast (240°/s) velocity of movements positively correlated with the mean W and P of the same muscles in the first ten and last ten isokinetic knee flexion-extension movements at the velocity of 240°/s. Therefore, preventive knee flexor muscle strength training programs for handball players are recommended. This training would cause increase the knee flexor/extensor muscles peak torques, mean work and power ratios not only in the first to tenth repetition of the knee flexion – extension movements, but also in greater amount of movements or improve the fatigue resistance of hamstrings.

**CONCLUSIONS**

Fatigue of the knee flexor muscles (hamstrings) appears faster than of the extensor muscles (quadriceps femoris) because the mean work produced by the knee flexors in the last ten flexion–extension movement repetitions was significantly smaller than in the first ten motions ($p<0.02$). The knee flexor/ extensor muscles mean work and power ratios in the last ten motions ($W_{\text{fl}}/W_{\text{ext}} = 0.69; P_{\text{fl}}/P_{\text{ext}} = 0.65$) were significantly lower in comparison with the first ten knee flexion–extension movements ($W_{\text{fl}}/W_{\text{ext}} = 0.73; P_{\text{fl}}/P_{\text{ext}} = 0.71$), $p<0.002$. Therefore the knee joint trauma may occur more probably in the end of the game or training.

The significant positive correlation between thigh (hamstrings and quadriceps femoris) muscles peak torques and the mean work and power of the same muscles in the first ten and last ten knee flexion-extension movements ($p<0.01$) confirms that the strength training of these muscle groups will improve not only the maximal strength but also the fatigue resistance of these muscles.
**Highlights**

The knee flexor/extensor mean work and power ratios decrease due to faster fatigue of hamstrings in comparison with quadriceps femoris is observed in sport game players. This can cause knee joint trauma. Strength training of hamstrings will improve the fatigue resistance of these muscles.

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**References**