Ett test av maximal knä flexor- och extensor styrka för att undersöka bilaterala skillnader hos Svenska elit hockey spelare.

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A comparison of maximal knee flexor and extensor strength for assessing bilateral imbalance in Swedish elite hockey players.

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Sammanfattning

Syftet

Syftet med studien var att bestämma knä extensorer och flexorers muskelstyrkeegenskaper hos en grupp professionella svenska hockeyspelare, och eventuella asymmetrier som ses i dessa.

Metod

Studien var utformad för att mäta styrka och kraft under en unilateral rörelse som omfattar de nedre extremiteterna i en öppen kedja . Resultaten från varje ben jämfördes mellan vänster och höger quadriceps (Q) och hamstrings (H), jämförelse med medel- och det högsta uppmätta värdet för förhållandet mellan hamstrings till quadericeps (H/Q kvot) och mellan dominant (D) och icke - dominanta (ND) ben för att beskriva eventuell obalans mellan benen. Dominant ben definierades som det starkaste uppmätta benet (Antingen höger eller vänster) från den insamlade datan för varje enskild spelare och sedan beräknat som ett värde för hela gruppen. Deltagarna genomförde en definierad uppvärmning och eventuell självald statisk stretching tilläts. Maximal koncentrisk (con) och excentrisk (ecc) quadriceps och hamstring styrka mättes vid isokinetiska knä extension och flexion både vid $90°\cdot s^{-1}$ och $300°\cdot s^{-1}$. En Isomed2000 (D&R Ferstl GmbH, Germany) användes för dessa mätningar.

Resultat

Vid jämförelse av D till ND sida, sågs signifikanta skillnader vid de högst uppmätta värderna för Q ($p = 0{,}0005$) och H på con $90°\cdot s^{-1}$ ($p = 0{,}027$) och H på ecc $90°\cdot s^{-1}$ ($p = 0014$). Vid en jämförelse av medelvärdet mellan D och ND sida sågs signifikanta skillnader för Q för $90°\cdot s^{-1}$ ($p = 0{,}026$) och H på ecc $90°\cdot s^{-1}$ ($p = 0{,}007$). När man tittar H/Q kvoten mellan höger och vänster sida sågs en signifikant skillnad för maximal kraft vid con $90°\cdot s^{-1}$ och en måttlig relation sågs hos medelvärden vid con $90°\cdot s^{-1}$ och ecc $90°\cdot s^{-1}$

Slutsats

Resultatet visar att elit hockeyspelarna i den testade gruppen verkar ha ett signifikant starkare ben och en svag hamstrings jämfört med quadriceps. Det innebär att de tenderar att vara asymmetriska vilket eventuellt kan påverka den idrottsliga prestandan, men kan eventuellt även öka förekomsten av skador. Detta måste dock utvärderas med ytterligare forskning i detta ämne.

Aim

The aim of this study was to determine knee extensor (Q) and flexor (H) muscle strength characteristics in a group of professional Swedish hockey players, including maximal isokinetic torque and any asymmetries seen in these.

Method

This study was designed to measure strength and power performance during unilateral movement involving the lower extremities in open chain. The contribution of each leg were discerned for subsequent comparison of left to right quadriceps (Q) and hamstrings (H), mean and peak value of hamstrings to quadriceps (H/Q ratio) and dominant to non-dominant legs for the purpose of examining imbalances between the legs. The dominant leg (D) was defined as the strongest leg (either right or left) from the collected torque data for each player and then calculated as one value for the whole group. Subjects had a defined warm-up session and any static stretching that subjects feel necessary to assist them in performing the tests was also permitted. Maximal concentric (con) and eccentric (ecc) quadriceps and hamstring muscle strength was obtained by measuring maximal force moments (torque) during isokinetic knee extension and flexion movements both in $90°\cdot s^{-1}$ and $300°\cdot s^{-1}$. An Isomed2000 (D&R Ferstl GmbH, Germany) was used for the measurements.

Results

In a comparison of D to ND, significant differences were obtained in peak torque for Q ($p=0,0005$) and H at con $90°\cdot s^{-1}$ ($p=0,027$) and H at ecc $90°\cdot s^{-1}$ ($p=0,014$). When comparing mean torque between D and ND significant differences were obtained for Q for con $90°\cdot s^{-1}$ ($p=0,026$) and H at ecc $90°\cdot s^{-1}$ ($p=0,007$). When looking at H/Q ratio between right and left sides a significant difference was seen for peak torque at con $90°\cdot s^{-1}$ and moderate relationship was seen at mean values at con $90°\cdot s^{-1}$ and ecc $90°\cdot s^{-1}$.

Conclusions

The result shows that the elite hockey players in the tested group seem to have one significant stronger leg and a week hamstrings compared to quadriceps. This means that they tend to be asymmetrical which might affect performance but may also increase the incidence of injury. This has to be evaluated with further research.

Table of Contents

Table and figure list

1 Background

Muscular strength is supposed to be one of the most important indicators of physical performance in sport, in terms of both high-level performance and injury occurrence (Lehance, Binet, Bury & Croisier 2009). Balance in strength and flexibility between the dominant and non dominant legs provide joint stability, particularly during dynamic movements in sports like handball, hockey and soccer. For the knee joint, co-activation of hamstrings and quadriceps may be critical to prevent or to reduce knee motion and loads that increase the risk of anterior cruciate ligament (ACL) injury. Hamstring recruitment reduces ACL loads from quadriceps (Renstrom, Arms, Stanwyck, Johnson & Pope 1986; Withrow, Huston, Wojtys & Ashton-Miller 2008) and may help to provide dynamic knee stability by resisting anterior and lateral tibial translation and transverse tibial rotations (Hewett, Linden, feld, Riccobene & Noyes 1999a) and therefore play an important role in sports with asymmetric kinetic patterns (Rahnama, Lees & Bambaecichi 2005; Fousekis, Tsepis & Vagenas 2010). Many factors, such as previous injury or specific sport demands can result in the development of muscle strength imbalances among athletes (Rahnama et al. 2005). However Newton et al (2006) (Newton, Gerber, Nimphius, Shim, Doan, Robertson, Pearson, Graig, Hakkinen & Kraemer 2006) showed that even athletes with extensive high quality strength and conditioning training backgrounds exhibited considerable imbalances in lower-limb strength and power performance and when bilateral movements such as the back squat and vertical jump were performed, force generation and contribution to the performance could be markedly different between sides.

Side-to-side strength imbalance in well trained athletes has previously been shown in several other studies (Gioftsidou, Ispirlidis, Pafis, Malliou, Bikos & Godolias 2008; Masuda, Kikuhara, Takahashi & Yamanaka 2003; Newton et al. 2006; Rahnama et al. 2005; Österberg, Roos, Ekdahl & Roos 1998) Such imbalances may not only affect performance but may also increase the incidence of injury which has been suggested in many studies (Croisier, Forthomme, Namurois, Vanderthommen & Crielaard 2002; Croisier, Reveillon & Ferret 2003; Knapik, Bauman, Jones, Harris & Vaughan 1991; Orchard, Marsden, Lord & Garlick 1997; Westin, Alricsson & Werner 2012). Westin (Westin et al. 2012) followed 431 students at ten different Swedish Ski High Schools prospectively during five years, and showed that there was a significantly higher risk for an elite alpine skier to sustain an injury of the lower extremity of the left side compared to the right side even though alpine skiers should perform ski turns equally well to the left and to the right side and therefore need the same physical requirements on their left and right sides. Their possible explanation for the finding was that the skiers already had a side-to-side difference and/or a dominant leg (range of motion, strength or neuromuscular control), which may influence the risk of getting injured.

Several investigators have suggested that the imbalance of the ratio between knee flexor and extensor muscle groups (H/Q ratio) registered during concentric muscle contraction is one of the important parameters in knee joint stability and used for evaluation of hamstrings injuries (Orchard et al. 1997) and the H/Q ratio has also been reported because of a possible relationship to ACL injuries (Eitzen, Eitzen, Holm, Snyder-Mackler & Risberg 2010; Russell, Quinney, Hazlett & Hillis 1995). In the literature this ratio is known as the conventional Hcon/Qcon ratio and it is calculated as knee flexor peak torque divided by peak torque of knee extensor muscles. Many authors provide the value of 0.5-0.8 as a normative for the H/Q ratio at $60°\cdot s^{-1}$ which increases up to 0,8-0.95 with increased movement velocity at $300°\cdot s^{-1}$ (Rosene, Fogarty & Mahaffey 2001; Wilk, Romaniello, Soscia, Arrigo & Andrews 1994; Hewett, Myer & Zazulak 2008; Devan, Pescatello, Faghri & Anderson 2004; Grygorowicz M. 2010; Wilkerson, Colston, Short, Neal, Hoewischer & Pixley 2004; Cheung, Smith & Wong del 2012; Bennell, Wajswelner, Lew, Schall-Riaucour, Leslie, Plant & Cirone 1998). The H/Q ratio depends on the velocity of the movement of the tested limb, as well as on the testing position and on the evaluated group (Aagaard, Simonsen, Trolle, Bangsbo & Klausen 1995; Worrell, Perrin & Denegar 1989).

Yamamoto J. (1993) concluded that the muscle imbalances between the legs, the hamstring strength and the ratio of the flexor to extensor were shown to be parameters related to the occurrence of hamstring strains in track and field athletes when they were followed over 2 years. They noticed that when the subjects were divided into injured and uninjured groups and compared using the various strength measures, the injured group had a greater bilateral imbalance, relatively weak hamstrings, and a lower knee flexion-extension ratio at the start of the study. Bilateral strength asymmetry of the knee extensors and flexors and hamstrings to quadriceps torque ratio is therefore widely used in sports medicine to quantify the functional deficits, to identify athletes at increased risk of incurring lower-limb injuries during training and competition, to monitor the effectiveness of sport rehabilitation programs, and to decide whether an athlete is ready to return to sport after rehabilitation (Clark 2001; Wilk, Reinold & Hooks 2003). In contrast, a few studies have also indicated that there is no relationship between strength imbalances and injury (Bennell et al. 1998; Knapik et al. 1991; Siqueria, Plegrini, Fontana & Greve 2002; Theoharopoulos, Tsitskaris, Nikopoulou & Tsaklis 2000).

Isokinetic dynamometry testing is the predominate method for assessment of muscle strength evaluation in the orthopaedic and sports medicine setting, both in healthy individuals and after ACL injury (Andrade, Cohen, Picarro & Silva 2009; Croisier et al. 2003; Croisier, Malnati, Reichard, Peretz & Dvir 2007; Fernandes, Protta, Neto, Pedrinelli, Camanho & Hernandez 2012; Newton et al. 2006; Reichard, Croisier, Malnati, Katz-Leurer & Dvir 2005). Isokinetic exercise is defined as a dynamic movement involving contractions at a preselected constant angular velocity whereby the resistance encountered is relative to the force produced by the individual (Wyatt & Edwards 1981). Isokinetic dynamometry is a frequently chosen method because of the inherent patient safety, objectivity and reproducibility in testing measures (Feiring, Ellenbecker & Derscheid 1990; Alexander 1990; Robert, Mccleary & Andersen 1992; Wilk, Lohnson & Levine. 1988). Most often, the interpretation of isokinetic test data has been limited to the assessment of peak torque (Aguilar, Distefano, Brown, Herman, Guskiewicz & Padua 2012; Kambis & Pizzedaz 2003; Kues, Rothstein & Lamb 1992; Alexander 1990; Pincivero, Gandaio & Ito 2003). Quadriceps peak torque represents the value of the one point during knee extension from 90-0° where the individual is able to produce the highest force (Tsepis, Giakas, Vagenas & Georgoulis 2004). Peak torque may give limited information about the muscle performance during the full selected range of motion (ROM) (Holm 1996; Wilk et al. 1994). Eitzen et al (2010) showed that the largest mean relative differences between the injured and the uninjured leg were established at knee flexion angles less than 40° They concluded that isokinetic curve profiles based on angle specific torque values provide more information on quadriceps muscle performance after ACL injury than the established use of peak torque values alone. Quadriceps deficits are in general more severe at knee flexion angles less than 40°, and this characteristic pattern is even more evident for ACL individuals classified as noncopers. They also showed that the curve profiles were reflected in single-hop performance.

Functional weight bearing movements will always involve motion in adjacent joints as well as the target joint. Thus, functional assessments will reflect multi-level performance and the open chain kinetic chain feature of isokinetic testing has been criticized for nonfunctionality which however enables specific quantification of deficits in isolated muscles (Andrade et al.

2009; Pua, Bryant, Steele, Newton & Wrigley 2008; Tsepis et al. 2004; Greenberger & Paterno 1995; Moss & Wright 1993).

To our knowledge, very few studies have investigated asymmetry of the knee in professional male hockey players. There are a few studies that have investigated hip asymmetry on professional male hockey players and they found that preseason hip adduction strength of the players who sustained groin injuries was 18% lower than that of the healthy players. They also found that adduction strength was 95% of abduction strength in the uninjured players, compared to only 78% in the injured players. This suggests that a muscular imbalance plays a large role in groin issues (Sim, Simonet, Melton & Lehn 1987; Masuda, Kikuhara, Demura, Katsuta & Yamanaka 2005). With respect to the knee injuries in professional hockey players in the world and relationship between strength deficit, strength ratio and flexibility with knee injuries, the main purpose of the present study was to investigate the bilateral and unilateral asymmetries of strength and flexibility in Swedish male professional hockey players.

2 Purpose

The purpose of the present study was to determine maximal concentric and eccentric muscle strength in isokinetic knee extension and flexion movements in a group of Swedish elite hockey players and to identify if there was an open chain strength asymmetry between the right and left or dominant and not dominant legs.

2.1 The aim

The aim of this study was to determine knee extensor and flexor muscle strength characteristics in a group of professional Swedish hockey players, including maximal isokinetic torque and any asymmetries seen in these.

The hypotheses were

- there is no strength asymmetry between dominant and non-dominant on group level
- there is no strength asymmetry between right and left quadriceps or hamstrings
- there is a strength asymmetry in H/Q ratio in both right and left legs

2.2 Meaning

The study intends to increase knowledge about determination of muscle imbalance and side strength differences. Possible implications of asymmetries in strength and functional tests with respect to identify a possible risk for injuries in the lower extremities will be discussed.

3 Materials and methods

3.1 Experimental Approach

This study was designed to measure strength and power performance during unilateral movement involving the lower extremities in open chain. The contribution of each leg was discerned for subsequent comparison of left to right and dominant to non-dominant legs for the purpose of examining imbalances between the legs. Description of what is dominant or non-dominant leg was made after the data had been collected and dominant leg is described in this study as the leg with the highest value measured for each muscle group that was tested for each player and then calculated as one value for the whole group. Subjects had a defined warm-up session and any static stretching that subjects feel necessary to assist them in performing the tests was also permitted.

3.2 Session day

Subjects were instructed to avoid strenuous exercise the day before testing. Prior to the test session, subjects were required to warm up by riding a stationary bicycle for 10 minutes at Borg Scale 13. Any static stretching that subjects felt necessary to be done to assist them in performing the tests was also permitted. They performed the isokinetic open chain testing. Verbal encouragement was provided during the test.

3.3 Subjects

Hockey players from Södertälje Sport Klubb (Sweden) who played in the Swedish hockey division Allsvenskan were asked to participate in the study. Their age, height, and body mass was measured. The subjects were all professionals and trained on a daily basis (2–4 hours per day). They had 10-20 years hockey experience. All recruited subjects had a continuous resistance training program incorporating strength and power training exercises for at least three years. All the subjects were informed of the procedures and the purpose of the study and their written informed consent was obtained.

3.4 Recruitment

Recruitment was during winter-spring 2012-13.

3.5 Implementation

Spring 2013.

3.6 Subjects

This investigation was a prospective cohort study. The sample consisted of 14 professional hockey players free of injury for at least 6 months prior to testing, recruited from a total of 22 players from Södertälje Sport Klubb in League division Allsvenskan. The sample was homogeneous in potential confounding variables, such as weight, height, age, training regime (1-3 games and 6–7 days of training per week), climatic conditions, level of play, resting periods and professional experience (at least 5 years). All subjects signed written informed consent to the conditions of the study.

3.6.1 Inclusion criteria

- Playing in the Swedish Hockey Division Allsvenskan
- Playing hockey for between 10–20 years
- A continual resistance-training program incorporating strength and power training exercises for at least 3 years.
- Train on a daily basis (2–4 hours per day)
- Age 18-36

3.6.2 Exclusion criteria

Any lower extremity reconstructive surgery in the past two years or unresolved musculoskeletal disorders that according to the project leader prevented participation with maximum effort.

3.7 Measurements

3.7.1 Isokinetic open chain measurements.

Maximal concentric and eccentric quadriceps and hamstring muscle strength was obtained by measuring maximal force moments (torque) during isokinetic knee extension and flexion movements. An Isomed2000 (D&R Ferstl GmbH, Germany) was used for the measurements.

A previous study has shown high reliability (Dirnberger, Wiesinger, Stoggl, Kosters & Muller 2012) for absolute values of knee extension and flexion measurements conducted with this dynamometer (ICC: 0.76 – 0.89). Subjects were seated and reclined 10° and secured with straps over the shoulders and fastened midchest. Hips and thighs were firmly strapped to the seat of the dynamometer. The axis of rotation of the dynamometer lever arm was visually aligned with the lateral femoral condyle, and the lower leg was attached to the lever arm of the dynamometer at the level of the lateral malleolus. Efforts for measurement were preceded by 10 minutes of warm-up and preconditioning in the testing device. For each specific velocity and contraction mode, 5 trials were performed. The interval of rest between trials was 45 to 90 seconds. All recorded moment signals were corrected for the gravitational pull on the segment masses located distal to the knee joint. The knee joint rotations were performed at slow (angular velocity, $90°\cdot s^{-1}$) as well as fast ($300°\cdot s^{-1}$) knee joint movements. These testing speeds have been widely used for muscle strength assessment (Masuda et al. 2005; Zakas 2006). Selecting low ($90°\cdot s^{-1}$) and high ($300°\cdot s^{-1}$) isokinetic testing speeds is essential for optimal strength evaluation, given that in slow muscle action the vast majority of motor units are recruited, while faster testing velocities enrich the force-velocity spectrum of the acting muscles (Baltzopoulos&Brodie 1989). Range of motion was 0° to 90° (0° indicating full extension). The ratio of the torque between the two muscle groups per leg and between legs was calculated. Again asymmetries between left to right, D to ND legs and H/Q ratio were determined.

3.8 Data Analysis

Descriptive statistics (mean ± SD) were calculated for the left and right leg cohorts, as well as the H/Q ratios. Right- to left side comparisons were made using paired t tests, and comparisons between D and ND leg on group level were made using unpaired t tests. We chose $P<0.05$ to represent statistical significance.

4 Ethical considerations

When performing strength tests subjects may get cramp or possibly a slight muscle strain in the tested muscle. On each test occasion, there was a physical therapist available to take care of any emergency medical procedures that could occur. We anticipated that participation would not have any immediate benefits for the subject, but on the other side if there was a difference between right and left legs of the test results, that information can potentially be used by the subjects to train the weaker side more to achieve the values measured for the

stronger side, which in previous research has shown to reduce the risk of injury. Information about the study's purpose, procedures, possible risks or benefits as well as the issue of participation has been informed verbally on several occasions. Ample time and opportunity for questions was provided throughout the whole process. Interest and consent to participate in the study were documented in the contract form and signed by the participant.
A continuation of this study is planned on an MSc level and the results are intended to be published in a scientific journal. Prior to this continuation an application for ethical approval will be sent to the Stockholm Regional Ethical Committee.

5. Results

No significant difference was seen in mean or peak torque for any of the isokinetic knee quadriceps and hamstrings tests at con $90°·s^{-1}$, ecc $90°·s^{-1}$ and con $300°·s^{-1}$ when comparing right and left legs (Table 1 and 2). In a comparison of D to ND, significant differences were obtained in peak torque for quadriceps (p=0,0005) and hamstrings at con $90·s^{-1}$ (p=0,027) and hamstrings at ecc $90°·s^{-1}$ (p=0,014) (Table 1). When comparing mean torque between D and ND (Table 2.) significant differences were obtained for quadriceps for con $90°·s^{-1}$ (p=0,026) and hamstrings at ecc $90°·s^{-1}$ (p=0,007). There were no significant differences between D and ND legs in either mean or peak torque for both quadriceps and hamstrings at con $300°·s^{-1}$ (p = 0,193-0,626) or for quadriceps at ecc $90°·s^{-1}$ (p=0,072-0,154) (Table 1 and 2). There was a trend towards higher mean torque in D compared to ND for the hamstrings at con $90°·s^{-1}$ (p=0,053) (Table 2).

TABLE 1.

Mean ± SD isokinetic knee extension and flexion peak torque at con $90°\cdot s^{-1}$, ecc $90°\cdot s^{-1}$ and con $300°\cdot s^{-1}$ with comparisons for left vs. right and dominant vs. nondominant in the test group.

Comparing	Right leg (Nm)	Left leg (Nm)	D leg (Nm)	ND leg (Nm)
Con 90°·s^{-1}				
Hamstrings	120,8 ± 13,5	115,8 ± 7,7	125,6 ± 11,3*	114,5 ± 11,4*
Quadriceps	228,2 ± 35,3	231,6 ± 21,5	239,2 ± 29,7*	214,9 ± 40,5*
Ecc 90°·s^{-1}				
Hamstrings	134,7 ± 21,4	128,0 ± 21,4	142,1 ± 17,0*	120,5 ± 20,0*
Quadriceps	251,3 ± 37,1	256,0 ± 49,5	270,6 ± 40,2	236,6 ± 40,0
Con 300°·s^{-1}				
Hamstrings	112,7 ± 18,9	117,8 ± 17,7	120,7 ± 18,7	109,8 ± 16,4
Quadriceps	157,7 ± 18,5	157,2 ± 13,2	163,6 ± 15,6	151,3 ± 13,8

***Significant difference ($p < 0.05$) between dominant and nondominant legs in hamstrings and quadriceps at Con $90°\cdot s^{-1}$. ***Significant difference ($p < 0.05$) between dominant and nondominant legs in hamstrings at Ecc $90°\cdot s^{-1}$

TABLE 2.

Mean ± SD isokinetic knee extension and flexion mean at con $90°\cdot s^{-1}$, ecc $90°\cdot s^{-1}$ and con $300°\cdot s^{-1}$ with comparisons for left vs. Right and dominant vs. nondominant in the testgroup.

Comparing	Right leg (Nm)	Left leg (Nm)	D leg (Nm)	ND leg (Nm)
Con 90°·s^{-1}				
Hamstrings	118,6 ± 14,0	114,0 ± 8,1	123,5 ± 11,6	112,5 ±11,7
Quadriceps	222,5 ± 32,7	227,3 ± 21,1	236,7 ± 21,8*	214,9 ± 26,8*
Ecc 90°·s^{-1}				
Hamstrings	128,7 ±23,1	119,1 ± 21,4	135,7 ± 16,0*	112,1 ± 22,2*
Quadriceps	239,7 ± 35,4	247,9 ± 43,6	256,6 ± 39,6	231,1 ± 35,6
Con 300°·s^{-1}				
Hamstrings	108,5 ±18,9	114,5 ± 17,0	117,5 ± 18,3	105,3 ± 16,0
Quadriceps	153,6 ± 18,5	153,3 ± 12,2	159,7 ± 15,1	147,2 ± 13,5

***** Significant difference ($p < 0.05$) between dominant and nondominant legs in hamstrings and quadriceps at Con $90°\cdot s^{-1}$. ***** Significant difference ($p < 0.05$) between dominant and nondominant legs in hamstrings at Ecc $90°\cdot s^{-1}$

When looking at mean and peak H/Q ratio between right and left sides a significant difference was seen for peak torque at con $90°·s^{-1}$ and moderate relationship was seen at mean values at con $90°·s^{-1}$ and ecc $90°·s^{-1}$ (Table 3 and 4). No difference was seen in the peak torque H/Q ratio between right and left legs at ecc $90°·s^{-1}$ or for mean or peak torque H/Q ratio at con $300°·s^{-1}$ (Table 3 and 4).

TABLE 3.

Mean ± SD of peak torque H/Q ratio for left and right legs at con $90°·s^{-1}$, ecc $90°·s^{-1}$ and con $300°·s^{-1}$.

Comparing	Right leg (%)	Left leg (%)
Con $90°·s^{-1}$	54,5 ± 7,9	50.8 ± 5,5*
Ecc $90°·s^{-1}$	55,3 ± 9,4	51,3 ± 10,7
Con $300°·s^{-1}$	71,7 ± 10,2	75,0 ± 9,8

* Significant difference ($p <0.05$) between right and left legs at Con $90°·s^{-1}$

TABLE 4.

Mean ± SD of mean torque H/Q ratio for left and right legs at con $90°·s^{-1}$, ecc $90°·s^{-1}$ and con $300°·s^{-1}$.

Comparing	Right leg (%)	Left leg (%)
Con $90°·s^{-1}$	54,4 ± 7,9	51,0 ± 5,5
Ecc $90°·s^{-1}$	54,6 ± 12,0	48,3 ± 7,0
Con $300°·s^{-1}$	70,9 ±10,8	74,7 ± 9,9

6. Discussion

6.2 Result discussion

The purpose of the present study was to determine maximal concentric and eccentric muscle strength in isokinetic knee extension and flexion movements in a group (n=14) of Swedish elite hockey players in Södertälje Sport Klubb and to identify if there was an open chain strength asymmetry between the right and left, dominant and not dominant legs on group level and in H/Q ratio. No significant differences between the left and right legs were found, but when D and ND on group level were determined from the collected torque data, there were significant differences.

This study also revealed significant strength differences for the H/Q ratio at con $90°·s^{-1}$ between right and left sides and a moderate difference was seen at mean values at ecc $90°·s^{-1}$ (p=0,126) and at con $90°·s^{-1}$ at mean values (p=0,143). This indicated that there is leg dominance on group level and that the lower extremities of elite hockey players in Södertälje Sport Klubb tend to be asymmetrical. No previous study was found investigating these factors in elite ice-hockey players.

The findings demonstrated an increase in the H/Q ratio with increasing speed, from the low (mean left 51,0 ± 5,5 at $90°·s^{-1}$and right 54,4 ± 7,9) at $90°·s^{-1}$compared to the high velocity (mean right 70,9 ± 10,8 and left 74,7 ± 9,9) at $300°·s^{-1}$which supported other studies showing an increase in H/Q ratio with increased speed (Hewett et al. 2008; Aagaard, Simonsen, Magnusson, Larsson & Dyhre-Poulsen 1998). However, when compared to normative data at $60°·s^{-1}$and $300°·s^{-1}$the group in our study showed that the mean right and left H/Q ratios were below the ‘‘normal’’ range of 80% to 95% at $300°·s^{-1}$. Most of the athletes manifested an H/Q ratio of less than 80% at $300°·s^{-1}$ (Table 3) indicating less hamstring strength relative to quadriceps strength in these elite hockey players compared to normative data.

Withrow et al (2008) along with others have shown a correlation between a strong hamstrings and less ACL tear. Athletes possessing ratios of less than 80% at $300°·s^{-1}$ (H/Q ratio) together with genu recurvatum had a greater occurrence of overuse knee injuries than those not having these musculoskeletal abnormalities (Devan et al. 2004). The question is still if muscle dysbalance around knee joint can cause various injuries, especially straining of the hamstrings group and ACL tear and if the correction of the antagonist muscle imbalance can reduce the risk of injury? So far this question has not been answered completely and there are studies showing conflicting results (Zvijac, Toriscelli, Merrick, Papp & Kiebzak 2014; Moeller & Lamb 1997; Hewett, Lindenfeld, Riccobene & Noyes 1999b; Huston & Wojtys 1996; Bennell et al. 1998).

A conventional H/Q ratio (Hcon/Qcon ratio) value about 0.5-0.8 is widely used as normative (Aagaard et al. 1998; Aagaard et al. 1995; Cheung et al. 2012), but further analysis and search for injury causes have to be undertaken, for it seems that research available today is not supportive enough to draw an ultimate conclusion about this value. Still, there is a significant quantity of research, acquired during isokinetic testing, which supports this value as an objective parameter that can be used for calculation of the risk of injury. However, the use of conventional H/Q ratio calculated as Hcon/Qcon has some restrictions. The H/Q ratio has conventionally been calculated as maximal knee flexion strength divided by maximal knee extension strength obtained at a given knee angular velocity and contraction mode (isometric, concentric, eccentric) (Grygorowicz M. 2010; Aagaard et al. 1998; Baltzopoulos & Brodie 1989; Kannus 1994; Osternig 1986). This is, however not a complex physiological movement as seen in sport-related activity and it has been suggested that the agonist-antagonist strength relationship for knee extension and flexion may be better described with a functional H/Q ratio by taking in consideration that concentric work of agonist group (knee extensors) is accompanied by simultaneous eccentric work of antagonist muscles (knee flexors). A functional H/Q ratio is therefore calculated as eccentric hamstring to concentric quadriceps muscle strength (Hecc/Qcon), representative of knee extension or concentric hamstring to eccentric quadriceps muscle strength (Hcon:Qecc, representative of knee flexion) Aagaard et al (Aagaard et al. 1998) showed in their study that the conventional H/Q ratios were 0.5 to 0.6 based on peak torque at 50°, 0.6 to 0.7 based on 40° moments, and 0.6 to 0.8 based on 30° moments at $240°\cdot s^{-1}$. They showed that conventional H/Q ratio increased with more extended knee joint positions while the functional H/Q ratios for fast knee extension were 1.0, 1.1, and 1.4 based on 50°, 40°, and 30° moments, respectively. So their major finding was that the functional H/Q ratio for fast knee extension was always 1.0 or greater, or approximately twice that of the conventional H/Q ratio. In other words, the functional H/Q ratio yielded a 1:1 hamstring to quadriceps strength relationship for fast knee extension, which increased well above 1.0 at the most extended knee joint positions. This is also discussed by Grygorowicz M. 2010. Perhaps further analysis of other parameters describing dynamic relationship between knee flexors and extensors (including eccentric muscle contraction), as proposed by Aagaard et al (1998), including the analysis of the strength-velocity relationship in specific ROM, will be even more effective in successful sports injury prevention. In our study, we used the H/Q ratio between peak torques in concentric hamstrings and concentric quadriceps contractions and that might be a limitation, but this allowed us to compare our data with previous studies in which this, conventional, H/Q ratio is most commonly evaluated.

Because of limited research on bilateral strength differences in athletes as a group, it is unclear whether these imbalances are a result of sport-specific training or of other factors such as difference in leg length, a dominant leg or previous injury. With the known resistance training background of these hockey players, it was surprising that such imbalances existed. It is an interesting and important finding of the study that even with extensive bilateral squat, dead lift, vertical jump, and other leg extensor training, significant contra lateral imbalances in strength persist as a group. These findings are also supported by Newton et al (Newton et al. 2006) and others (Rahnama et al. 2005; Gioftsidou et al. 2008; Masuda et al. 2003; Newton et al. 2006; Österberg et al. 1998). Without further research, it can only be hypothesized that these imbalances between the D and ND leg may occur during hockey training and competition and that specific resistance training targeting the weaker side may be required to decrees the risk of injury.

Given the suggested important role of the hamstrings in stabilizing the knee, and in particular in protecting the ACL, hamstring strains and other knee injuries, it is important to discover imbalance between legs and to identify an H/Q ratio that is greater than the suggested nominative data. A strength imbalance may possibly affect an athlete's performance for instance by increasing the risk of injury or by limiting the hockey player to favouring their D side. Such a limitation or preference is perceived as a weakness in hockey where the ability to utilize both sides equally could enhance performance.

Further research is necessary to more completely evaluate if those hockey players with a big difference between right-left quadriceps and right-left hamstrings strength and in H/Q ratio have a higher risk of knee injuries than other hockey players with less differences.

6.2 Method discussion

We discussed if we should have included isokinetic tests even at $60°\cdot s^{-1}$, because that had been done in many other studies that measured and discussed H/Q ratio, but we decided to only include $90°\cdot s^{-1}$ and $300°\cdot s^{-1}$ because we thought it would be more sport specific to do the tests with higher velocities which has been suggested previously (Greenberger & Paterno 1995; Lephart, Perrin, Fu, Gieck, McCue & Irrgang 1992; Barber, Noyes, Mangine, McCloskey & Hartman 1990). It would also have been interesting to ask participants which leg they considered to be their dominant leg and then compare it with which leg had the highest value measured in the tests, but this was not done.

In this study we only included hockeyplayers from Södertälje Sport Klubb and it might have been a different result if we had included players from other clubs with another training protocol and with another type of strategy when playing ice hockey. These findings are important if all hockey players with extensive and quality strength and conditioning training backgrounds exhibit considerable imbalances in lower-limb strength. Further research needs to be conducted to determine just how important it is for athletes to possess bilateral strength balance. Although significant differences were found among all tests conducted, it is still hard to determine how much more likely one might be to suffer injury because of that imbalance and how their performance on ice might be affected.

When performing functional performance tasks it is therefore important to provide an equal stimulus to both legs to ensure balanced development of the lower legs and to prevent bilateral strength asymmetry from developing or increasing, which may be a possible risk factor for musculoskeletal injuries. Functional weight bearing movements will always involve motion in adjacent joints as well as the target joint. Thus, functional assessments will reflect multi-level performance and as mentioned earlier, the open chain kinetic feature of isokinetic testing has being criticized. (Andrade et al. 2009; Pua et al. 2008; Tsepis et al. 2004). Therefore, and with contradictions in the literature, it is important to gain more knowledge in the area of how to test strength imbalance in athletes and its indication for sport performance and ability to predict injury. So when measuring strength as sport specific as possible should it be done closed- or open chain?

Blackburn and Morrissey (1998) concluded that lower limb extensor closed kinetic chain muscle strength were more highly related to jumping performance than knee extensor open kinetic chain strength. Requena et al (2009) (Requena, Gonza´lez-BadilloSaez , De Villareal, Ereline, Garcı´a, Gapeyeva & Pääsuke 2009) concluded that in semi-professional soccer players isometric and isokinetic muscle strength assessed in an open kinetic chain were not movement-specific enough to predict performance during a more complex movement, such as jump or sprint while concentric half-squat exercise (closed chain) was principally related with the functional tests selected. That closed kinetic chain movements and fast muscle actions involving the stretch-shortening cycle are more functional in nature and more related to sport activities has has been indicated by a number of researchers (Cordova & Armstrong 1996; Findley & Lansky 1999; Ross 1997; Steiner, Harris & Krebs 1993; Abernethy, Wilson & Logan 1995). We therefore suggest further research comparing open- and closed chain tests, for instance whether an asymmetry in the lower extremities when tested with open chain would correlate with closed chain tests.

6.3 Conclusion

The result shows that the elite hockey players in the tested group seem to have one significant stronger leg and a week hamstrings compared to quadriceps. This means that they tend to be asymmetrical which might affect performance but may also increase the incidence of injury. This has to be evaluated with further research.

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