Sports Science

Lateral and functional asymmetries in the lower limbs of college-level female handball players

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Abstract - Aim: The present study aimed to screen for differences in isokinetic peak torque, hamstrings-to-quadriceps ratio, and proprioception within the lower limbs of female handball athletes. **Methods:** Twelve college-level female handball athletes with no previous experience with resistance training performed five maximal isokinetic contractions of the knee extensors and knee flexors to determine isokinetic peak torque and hamstring-to-quadriceps ratios. Proprioception was determined by assessing passive position sense on an isokinetic dynamometer. **Results:** The athletes presented significantly greater ($p < 0.01$) knee extensors isometric peak torque for the jumping limb (144.9 ± 23.1) when compared to the non-jumping limb (132.9 ± 21.5). The Hamstrings-to-quadriceps ratio was below 0.6 for both limbs, being significantly greater ($p < 0.01$) for the non-jumping limb (0.56 ± 0.08) when compared to the jumping limb (0.50 ± 0.08). **Conclusion:** Female handball athletes that do not engage in resistance training can experience functional bilateral asymmetries in the knee extensors and knee-joint instability, as assessed by the hamstrings-to-quadriceps ratio due to the asymmetric characteristics of handball. Regular strength training might correct such asymmetries and instabilities.

Keywords: Team sports, Strength, Proprioception, Hamstrings-to-quadriceps ratio.

Introduction

Handball (HB) is an invasion-based collective sport in which players must physically and technically overcome their opponents in order to score goals[1]. It is usually classified as predominantly aerobic by some authors, although athletes frequently perform high-intensity powerful efforts like jumps, shots, and tackles during matches[2,3]. To optimally perform such athletic actions, professional athletes tend to present greater stature, body mass, arm span, and muscle power compared to general populations[4-6]. Nevertheless, HB athletes, especially females, suffer a great number of injuries, with sprains and strains of the knee and ankle being the most frequent[7,8].

Although the entire body is involved in the execution of basic actions of HB, laterality is an important factor for the modality. Even though professional athletes can successfully perform most of the key actions (i.e., passes, shots and receptions) in HB with both limbs, they usually prefer to perform them with their dominant upper limb[9-11]. Thus, to achieve greater efficacy and power in such actions, HB athletes tend to jump with their non-dominant lower limb, which is also referred to as jumping limb (JL). This biomechanical characteristic is adopted as a strategy to stabilize the center of mass, resulting in a rotation of the trunk that helps building momentum and increases power output and throwing speed[12,13].

Hence, morphological and functional traits are usually greater in the upper dominant and lower non-dominant limb muscles of HB players due to the asymmetrical characteristic of the main powerful actions of the sport[13]. If not corrected by strength training, such asymmetrical development might lead to serious functional differences between limbs, which can increase susceptibility to injury[14,15]. Moreover, since a great number of jumps are performed by HB athletes, another risk to which they are exposed is the unbalanced force-generating capacity between the knee extensors (KE) and flexors (KF), compromising a ratio known as the hamstring-to-quadriceps ratio (H/Q_{ratio}). The H/Q_{ratio} is calculated by dividing the peak torque produced by the KF by the peak torque produced by the KE[16]. H/Q_{ratio} should range between 0.6 and 0.75[17,18], otherwise muscular imbalance in the knee joint is diagnosed.

H/Q_{ratio} has been thoroughly studied in athletes as well as active subjects[16,19,20]. However, greater scientific attention has been given to soccer players[14,17]. Andrade and colleagues[19] investigated the H/Q_{ratio} during isokinetic contractions at two different speeds in HB athletes. They found that female HB athletes presented muscular imbalance in the knee joint (i.e., $H/Q_{ratio} < 0.6$) when contractions were performed at $60°.s^{-1}$. Moreover, evidence suggests that proprioception might play an important role in reducing injury risk[21-23]. Proprioception is frequently measured as position or movement sense. Position sense measures an individuals' capacity to identify a given joint angle and reproduce it either actively or passively[24]. Thus, such tests make it possible to identify sensory-motor deficits that could result in great levels of stress imposed on a determined joint during changes of direction[7].

The present study aimed to screen for differences in isokinetic peak torque, $H/Q_{ratio,}$ and proprioception within the lower limbs of female HB athletes. Considering that the main athletic actions in HB are unilateral, and injury susceptibility might be increased by a muscular imbalance in the knee joint and within limbs, we hypothesized that: 1) Female HB athletes' JL would be significantly stronger than their non-jumping limbs (NJL); 2) H/Q_{ratio} would be significantly different between limbs for this sample.

Methods

Participants

Twelve college-level female HB players with no recent history of muscular or articular injury and no resistance training background volunteered to participate in the present study. Participants had at least 3 years of experience as HB athletes and competed in statewide college-level tournaments as well as regional amateur leagues and tournaments in the state of São Paulo, Brazil. Participants were recruited from the same college-level team, which explains the relatively small sample size of the present study, as goalkeepers and less experienced athletes were not included in the sample. Participants' playing positions were wingers (n = 5), backcourt players (n = 4) and pivots (n = 3). Their mean age, height, and body mass were 22.4 ± 2.5 years, 162 ± 5.9 cm, and 62.7 ± 12.5 kg, respectively, and they were informed about all the testing procedures and signed an informed consent, which was approved by the institutional Ethics Committee. The procedures of the present study are in accordance with the Declaration of Helsinki for the use of humans as experimental subjects and were approved by the institutional ethics review board under CAAE 33739614.1.0000.5465.

Testing procedures

All tests were performed using an isokinetic dynamometer (System 3, Biodex Systems, Shirley, NY, U.S.A.) to which all participants were already familiarized. To ensure validity and reproducibility of the data, participants were positioned on the dynamometer following guidelines provided by the manufacturer, having their trunks, hips, and thighs firmly secured to the chair and their legs firmly attached to a shaft that was connected to the load cell. Before performing the assessments, participants performed a five-minute warm-up on a cycle ergometer with a load of 25 W, followed by a specific warm-up in the dynamometer consisting of 3 submaximal isokinetic contractions at $60°.s^{-1}$.

To determine knee joint passive position sense (PPS), participants had their eyes covered by a comfortable strap and their knees positioned at a target angle of 30° of knee flexion for 10 seconds and were instructed to memorize that position. After that, they had their knees positioned at 90° of knee flexion. The dynamometer then extended participants' knees at a $5°.s^{-1}$ angular velocity and they were instructed to press a stop button whenever they thought their knees were positioned at the target angle they memorized (i.e., 30 °). The angle at which the participants pressed the stop button was recorded as the reported angle. This procedure was repeated 3 times. The error was calculated as the absolute difference between the reported angle and the target angle.

Isokinetic peak torque (IPT) of the KE and KF were obtained by performing 5 maximal isokinetic concentric contractions at a contraction velocity of $60°.s^{-1}$. The range of motion adopted was 70°, ranging from 90° to 20° of knee flexion. Contractions of the KE and KF were performed in an alternated fashion. Gravitational correction and filtering of the data were performed by the dynamometer's software. Mean IPT values during the 5 contractions for each muscle group were calculated and used for further analyses. H/Q_{ratio} was calculated by dividing KF IPT by KE IPT.

Statistical analyses

Data normality was tested by Shapiro-Wilk's test. Differences in all dependent variables between limbs were compared by Student's t-test for independent samples. The significance level was set at $p \leq 0.05$. Data are expressed as mean ± SD.

Results

Individual and mean values for IPT and PPS values are represented in Table 1. Knee extension IPT was 8.1%

greater ($p < 0.01$) for the JL when compared to the NJL. No significant differences between limbs were found for knee flexion IPT ($p = 0.32$), nor PSS ($p = 0.38$) error.

H/Q_{ratio} was below 0.6 for both limbs. However, it was 13.4% greater ($p < 0.01$) for the NJL when compared to the JL. H/Q_{ratio} values are represented in Figure 1.

Discussion

The present study aimed to screen for functional differences between lower limbs of college-level HB players. Profiling studies are useful for coaches and practitioners, since they may determine normative data or, in the specific case of the present study, highlight areas that claim more attention from these professionals. The main findings of the present studies were: (1) there is a significant difference in KE strength between lower limbs of HB players who are not engaged in regular strength training; (2) H/Q_{ratio} of both lower limbs is beneath expected levels for knee joint stability (i.e., 0.60-0.75); and (3) this imbalance is greater in the JL.

HB performance depends on a wide variety of in- and off-game aspects[38,39,40]. Wagner et al.[25] classified these aspects as an individual (coordination, strength, endurance, constitution, and nutrition), team-related (cognitive, social, tactical, and numerical), and external (environmental and equipment-related). Even though all these aspects contribute to overall HB performance, throwing efficacy can be considered paramount for success in this sport[25] since it is the last offensive action preceding a

Table 1 - Individual and mean values for knee extension and knee flexion isokinetic peak torque (IPT) for the jumping limb (JL) and non-jumping limb (NJL). *p < 0.01 comparing the jumping limb and non-jumping limb values.

	Knee extension IPT (N.m)			Knee Flexion IPT (N.m)			Passive Position Sense (°)		
Athlete	JL	NJL	Difference (%)	JL	NJL	Difference (%)	JL	NJL	Difference (°)
1	152.3	140.9	8.1	84.1	86.6	-2.9	2	3.5	1.5
2	167.2	130.3	28.3	78.6	55.7	41.1	3	4	1.0
3	130.6	126.2	3.5	83.0	85.6	-3.0	3	6	3.0
4	118.1	105.7	11.7	62.2	71.1	-12.5	4	6	2.0
5	173.6	158.9	9.3	88.4	93.8	-5.8	7	5	-2.0
6	132.9	117.2	13.4	61.5	60.5	1.7	3	3	0.0
7	185.4	177.3	4.6	72.1	82.8	-12.9	3.5	2.5	-1.0
8	158.9	143.4	10.8	77.8	75.2	3.5	5	2.5	-2.5
9	118.2	107.7	9.7	48.7	56.7	-14.1	11	3	-8.0
10	115.1	115.0	0.1	64.1	73.2	-12.4	7	2	-5.0
11	141.7	124.8	13.5	66.1	66.7	-0,9	3.5	4.5	1.0
12	145.2	147.1	-1.3	72.4	85.3	3.5	3.5	3.5	0
Mean	144.9	132.9	9.3*	71,6	74.4	-2.8	4.6	3.8	-0.8
SD	23.1	21.5	7.7	11,5	12.7	15.3	2.5	1.3	3.2

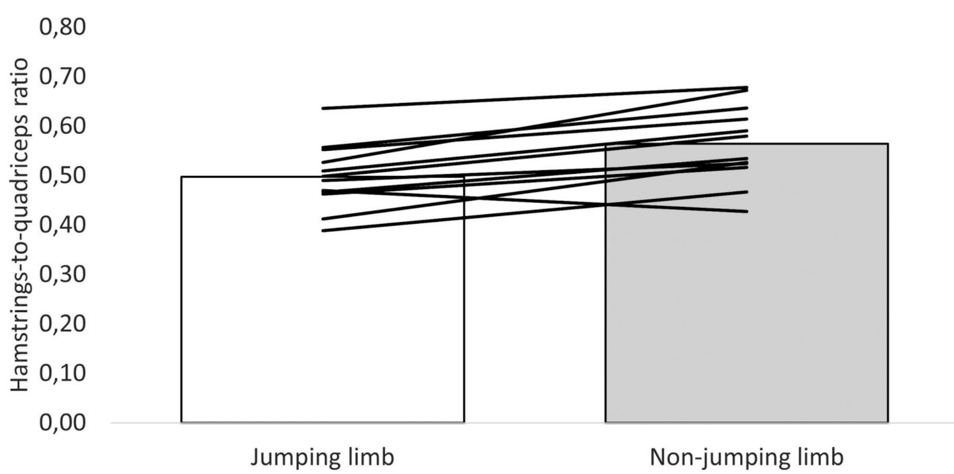

Figure 1 - Hamstring-to-quadriceps ratio values for both limbs. Bars represent the mean and lines represent individual differences between limbs for each athlete. *p < 0.05 compared to the jumping limb.

goal. Wagner et al.[13] reported that the fastest ball velocity in HB was attained in standing throws with run-ups. However, the most commonly adopted throw in HB is the jump throw, representing 75% of all throwing efforts during HB matches[25]. This prevalence of jump throws seems to be related to timing and positioning since athletes attempt to overcome defensive block height by jumping, also gaining more time for decision-making while in mid-air. It should be noticed, however, that the use of jump throws is highly dependent on the context of the match[38]. As an example, throws performed by pivots are frequently executed during intentional falls and/or horizontal leaps.

The present study confirmed the hypothesis that KE IPT is significantly different between limbs in college-level HB players. This difference can be explained by asymmetrical stimulation between limbs during training and matches, due to the higher prevalence of powerful contractions (i.e., jumps and landings) of the JL muscles during in-game activities in HB[9]. Bilateral strength imbalance (i.e., between the JL and NJL) is associated with susceptibility to injury in the weakest member[15]. Hence, Dauty et al.[15] suggest that correctional strength training should be performed if bilateral asymmetry is greater than 10%. Moreover, Wrigley[26] suggests that bilateral asymmetry greater than 15-20% may significantly increase the risk of injury and can be a consequence of the previous injury.

In the present study, a 9.3% bilateral asymmetry was identified for KE IPT. Even though it is still marginally below the 10% limit proposed by Dauty et al.[15], more than one-third of the sample (i.e., five athletes) presented bilateral asymmetry greater than 10% for KE IPT. In such cases, correctional strength training is warranted. Furthermore, half of our sample (i.e., six athletes) was diagnosed with bilateral asymmetry for the KF and should also undergo correctional strength training.

Susceptibility to knee injury can be influenced by extrinsic (i.e., environmental conditions, type of surface, footwear) and intrinsic factors (i.e., anatomical, hormonal, and neuromuscular factors)[27]. The H/Q_{ratio} has been proposed as one of the most important intrinsic predictors of knee joint stability by many authors[19,28,29]. By assessing H/Q_{ratio}, it is possible to screen for ipsilateral knee flexor-to-extensor imbalance, which might increase susceptibility injury in the knee flexors and other soft tissues surrounding the knee joint[15,30].

The H/Q_{ratio} data obtained in the present study shows that female college-level HB athletes with no experience with resistance training present knee imbalance between the KEs and KF both on the JL and the NJL. However, H/Q_{ratio} was greater for the NJL when compared to the JL, which suggests greater ipsilateral imbalance and, hence, greater susceptibility to injury in the JL. This can be explained by the biomechanical characteristics of HB, as the KE of the JL frequently performs powerful concentric contractions during matches in activities such as jumps. Moreover, intense eccentric contractions are also frequently performed with the KE of the JL during landings, as athletes tend to land with the same limb used for takeoff. It is reasonable to assume that greater stress imposed on the KE, as compared to the KF, leads to greater strength-related adaptations throughout the athlete's life. This explains the imbalance in force production capacity found between KE and KF in the present study.

Although we did not find significant differences among limbs in markers of proprioception in the present study, evidence suggests that improving lower-limb position sense might reduce the risk of injury caused by functional imbalance. Pánics et al.[7] showed that joint position sense can be improved in HB athletes through proprioceptive training which, in turn, reduces injury susceptibility in different sports modalities[23,31]. The main goal of proprioception training protocols adopted in most studies[7,21,32] is to improve spatial consciousness and control of the knees and ankles while in an upright position in situations that simulate the most frequent actions of each specific sport (i.e., sprints, decelerations, jumps, and landings). The most frequently used equipment for such training sessions are wobble boards, instability balls, bosus, and other soft surfaces. Coaches and fitness trainers must instruct athletes to focus on movement quality and stability during proprioceptive training.

Strength training has been widely studied and seems to be an effective strategy to attenuate functional imbalance and decrease injury susceptibility[21,33,34]. Achenbach et al.[33] showed that strength training prevents severe knee injuries in adolescent HB athletes and, therefore, should be included in their training regimen. Moreover, Mandelbaum et al.[21] showed that stretching, strengthening, plyometrics, and agility training reduce the number of ACL injuries in adolescent female soccer players. The functional asymmetries diagnosed in the present study can increase the risk of injury in the studied population, as they are considered as an intrinsic risk factor for knee joint injury. Therefore, some strategies could be adopted to control such risk by attenuating imbalances.

Unilateral strength training seems to effectively reduce functional asymmetries, as reported by Gonzalo-Skok et al.[35]. Similarly, Sannicandro et al.[36] found significant reductions in functional lower limb asymmetries in tennis players following a training protocol involving unilateral strength and proprioception training with medicine balls, elastic bands, dumbbells, and instability platforms. Finally, a recent meta-analysis comprising randomized controlled trials showed that multimodal training programs involving balance (static and dynamic), plyometric, strength, and power training positively influence athlete's neuromuscular performance, which in turn fundament the preventive efficacy of such training programs[37].

The limitations of the present study include the relatively small sample used and the fact that the athletes recruited for this investigation were all from the same college-level team, which may limit the generalizability of the present results. The inclusion of HB athletes of different playing positions must be considered in the interpretation of the present data since position-related differences in movements during matches as well as physical characteristics[40] of HB players can influence performance and functional imbalances. Moreover, we determined H/Q_{ratio} by the concentric KF IPT and KE IPT, which does not consider other neuromuscular variables that can influence the relationship between agonist and antagonist muscle groups and risk of injuries, such as the eccentric force capacity of KF and the capacity of the KF and KE to produce force rapidly[41]. Therefore, future investigations should focus on alternative methods of determining H/Q_{ratio} and neuromuscular function to provide additional information on lower-limbs functional asymmetries of college-level female HB players. Additionally, further investigation is warranted to determine the influence of athletes' playing position on muscular imbalances in the knee joint and within lower limbs.

Conclusion

The results of the present study show that female HB athletes that are not engaged in regular strength training regimens suffer from both ipsi- and bilateral functional asymmetries due to disproportional stimulation during in-match actions. Such asymmetries can increase susceptibility to injury in the knee joint and compromise the health of these young female athletes and, possibly, their careers. Therefore, adherence to strength and proprioception training programs are warranted to prevent functional asymmetries and attenuate the risk of injury to the knee joint in this population.

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