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Are Previous Joint Injuries Associated with Muscle Performance in Volleyball Athletes?*

Lesões articulares prévias são associadas ao desempenho muscular de jogadores de voleibol?

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Abstract

Objective The aim of the present study is to determine whether previous shoulder and knee injuries were associated with isokinetic fatigue index and agonist/antagonist ratio of shoulder internal/external rotators and knee flexors/extensors in male volleyball athletes.

Methods The current study is a cross-sectional investigation of 49 male elite volleyball players competing at a high level in Brazil. Isokinetic fatigue index and agonist/antagonist profiles were assessed during the preseason. Additionally, in order to record previous injuries, the athletes answered a standardized questionnaire. We conducted a receiver operating characteristic (ROC) curve analysis to determine the association strength and the clinically relevant cut-off point for variables presenting statistical significance for the area under the curve (AUC) ($\alpha = 0.05$). An independent t-

Keywords
- knee injuries
- muscle strength
- shoulder injuries
- volleyball

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test was used to compare isokinetic variables between athletes with and without previous injury (α = 0.05).
Results The results of the ROC curve analysis indicated that hamstring fatigue index values at 300°/s were associated with the presence of previous knee injury (area under the curve [AUC] = 73%, $p = 0.004$), and shoulder external rotators fatigue index values at 360°/s were not associated with the presence of previous shoulder injury (AUC = 68%, $p = 0.053$).
Conclusions Elite volleyball athletes who reported previous knee injuries were prone to a higher fatigue index than those reporting no injuries. Knee flexor resistance training might be useful for those athletes who reported knee injuries in the previous season.

Resumo

Objetivo O objetivo deste estudo é determinar se lesões prévias de ombro e joelho estavam associadas ao índice de fadiga isocinética e razão agonista/antagonista dos rotadores internos/externos do ombro e flexores/extensores do joelho em jogadores de voleibol.
Métodos Esta é uma investigação transversal com 49 jogadores de voleibol de elite que competem em alto nível no Brasil. O índice de fadiga isocinética e os perfis de agonistas/antagonistas foram avaliados durante a pré-temporada. Além disso, para registro de lesões anteriores, os atletas responderam a um questionário padronizado. Conduzimos uma análise da curva de característica de operação do receptor (*receiver operating characteristic*, ROC) para determinar a força de associação e o ponto de corte clinicamente relevante de variáveis com significância estatística na área sob a curva (AUC) (α = 0,05). Um teste t independente comparou as variáveis isocinéticas entre atletas com e sem lesão prévia (α = 0,05).
Resultados Os resultados da análise da curva ROC indicam que os valores do índice de fadiga dos isquiotibiais a 300°/s foram associados à presença de lesão prévia no joelho (área soba a curva [AUC] = 73%, $p = 0{,}004$), enquanto os valores do índice de fadiga dos rotadores externos do ombro a 360°/s não foram associados à presença de lesão prévia no ombro (AUC = 68%, $p = 0.053$).
Conclusões Atletas de voleibol de elite que relataram lesões anteriores no joelho estavam propensos a um índice de fadiga maior do que aqueles que não relataram lesões. O treinamento de resistência de flexores do joelho pode ser útil para atletas com relatos de lesões no joelho na temporada anterior.

Palavras-chave
- força muscular
- lesões do ombro
- traumatismos do joelho
- voleibol

Introduction

Bahr and Bahr[1] reported a total volleyball injury incidence rate of 1.7 ± 0.2 per 1,000 hours of play. Shoulder and knee overuse injuries represent from 15 to 50% of all volleyball injuries.[2] Verhagen and colleagues[2] indicated that shoulder injuries account for the longest duration of time away from training and competition (6.2 weeks).

Some authors investigated the relationship between muscle strength and overuse injuries in volleyball athletes.[3–7] Commonly, these studies analyze the isokinetic torque or agonist/antagonist ratio and do not consider other parameters such as fatigue index. Suzuki and Endo[8] evaluated the fatigability of the trunk muscles using the isokinetic dynamometer and found that patients with chronic low back pain had greater fatigue of the trunk flexors than healthy controls. Moreover, Souza and Powers[9] evaluated muscle endurance of the hip extensors in females with and without patellofemoral pain (PFP) and observed 49% fewer hip extension repetitions in females with PFP.

Muscle endurance (fatigue resistance) can be defined as the ability to produce work overtime or the ability to sustain effort.[10] Fatigue combines physiological mechanisms occurring at the central and peripheral levels; it can affect afferent and efferent neuromuscular pathways, as evidenced by delayed muscle response.[10] In volleyball, high-intensity efforts are often required for extended periods, and athlete fatigue is likely to occur. It seems feasible, therefore, that fatigue effects may compromise neuromuscular control responses to the point that abnormal and potentially hazardous movement strategies are inevitable.[10,11] Additionally, muscle fatigue has been related to decreased performance (water polo) and lower limb malalignment.[12,13] Therefore, volleyball athletes should participate in an assessment of shoulder and knee resistance to fatigue during preseason.

Agonist/antagonist ratio, peak torque, and work are frequently studied; however, information about injury effects and muscle endurance after joint injuries is limited.[14–17] Therefore, we aimed to verify whether previous shoulder and knee injuries were associated with isokinetic agonist/antagonist ratio and fatigue index of shoulder internal/external rotators and knee flexors/extensors in male volleyball athletes.

Methods

Forty-nine male elite volleyball players (mean ± standard deviation [SD] age, 21.96 ± 4.1) were recruited from 2 teams during the preseason. The inclusion criteria were participation on team schedule and no history of upper or lower extremity surgery during the previous year. Athletes who claimed shoulder or knee pain during the isokinetic test were excluded. All participants read and signed the informed consent form (Ethics Committee nº 0493.0.203.000-09).

The design of the study was observational research (cross-sectional).

All eligible athletes filled out a questionnaire regarding previous and present shoulder and knee injuries. This questionnaire included information about anthropometric characteristics, sports practice, and injury mechanisms. We defined previous injuries as any physical complaint that led to sports practice absence before the current preseason assessment. Then, all athletes performed the knee isokinetic test, and, after a 1-day interval, they performed the shoulder isokinetic test.

For the knee isokinetic assessment, the athletes performed a warm-up (5 minutes running) and were positioned at 85° hip flexion. Stabilizing straps were fixed on the pelvis, trunk, and thigh. The knee range of motion (ROM) was limited at 100°, starting at 110° knee flexion and finishing at 10° knee flexion.[18] The hamstring (H) and quadriceps (Q) ratio was registered at 60°/s and 300°/s, and fatigue index at 300°/s for the dominant knee[18] (►**Fig. 1a**).

On the 3rd day, the athletes were seated on the isokinetic chair, and the examiner positioned the dominant shoulder at 60° abduction, 30° horizontal adduction (scapular plane), and 90° elbow flexion[19] (►**Fig. 1b**). Stabilizing straps were fixed on the pelvis and trunk. Shoulder ROM was limited at 90°, starting at 50° shoulder internal rotation (IR) and finishing at 40° shoulder external rotation (ER), considering 0° as the forearm on horizontal position. The internal (IR) and external rotation (ER) ratio was collected at 60°/s and 360°/s, and fatigue index at 360°/s.[19] Six athletes did not show up for the shoulder isokinetic assessment performed on the 2nd day of data collection (due to personal reasons). Therefore, 43 athletes (mean ± SD age 21.30 ± 4.19; height 1.96 ± 0.06, and body mass 89.98 ± 8.83) completed the shoulder isokinetic test.

We performed descriptive statistics to characterize the sample. An independent t-test was used to compare the isokinetic variables between athletes with and without previous injury. A receiver operating characteristic (ROC) curve used to determine a clinically relevant cut-off point for each isokinetic variable reached statistical significance for the area under the curve (AUC) ($\alpha = 0.05$). The cut-off point was selected based on the largest distance from the reference line and sensitivity and specificity values. Prevalence ratios (PRs) and 95% confidence interval (CI) were calculated to determine association strength.

Fig. 1 Knee and shoulder isokinetic assessment.

Results

The data indicated 22 (44.90%) athletes had a previous knee injury and 29 (67.44%) had a previous shoulder injury. ►**Table 1** indicates the characterization of all athletes included in our study.

►**Table 2** indicates a comparison of mean and SD values for isokinetic variables of knee and shoulder joint of athletes. No differences between the groups (with and without previous injury) were found.

►**Table 3** shows the results of the ROC curve. Hamstring fatigue index values at 300 º/s were associated with the presence of previous knee injury (AUC = 73%). The cut-off point was 57.50 (sensitivity of 77% and specificity of 67%) for fatigue index of hamstrings at 300 º/s. Prevalence ratio values of 3.37 (95% CI = 1.34–8.50) were retrieved for hamstring fatigue index at 300º/s of ER.

Discussion

The purpose of the present study was to verify whether previous shoulder and knee injuries were associated with

Table 1 Preseason assessment data of all athletes (n = 57)

Demographics	Mean (SD)	Min–Max
Age (years)	21.96 (4.16)	17–33
Body mass (Kg)	89.17 (9.03)	68–106
Height (m)	1.96 (0.06)	1.77–2.08

Abbreviation: SD, standard deviation.

Table 2 Comparison between athletes with and without previous injury

Knee joint	With previous injury	Without previous injury	*P*-value
Fatigue flex 300 °/s	62.46 (6.02)	55.66 (9.29)	0.12
Fatigue ext 300 °/s	47.67 (10.27)	47.88 (7.25)	0.52
H/Q ratio 60°/s	51.75 (5.72)	50.10 (7.85)	0.44
H/Q ratio 300°/s	65.81 (11.15)	63.14 (9.80)	0.42
Shoulder joint	**With previous injury**	**Without previous injury**	***P*-value**
Fatigue ER 360 °/s	52.25 (25.73)	38.14 (14.75)	0.09
Fatigue IR 360 °/s	32.56 (17.25)	42.48 (12.98)	0.15
ER/IR Ratio 60°/s	71.80 (14.52)	67.87 (16.28)	0.64
ER/IR Ratio 360°/s	57.88 (19.50)	62.60 (20.50)	0.78

Abbreviations: ER, external rotation; H/Q, ; IR, internal rotation.

Table 3 Receiver operating characteristics curve results

Knee joint	AUC	95% CI	*P*-value
Fatigue Fl 300 °/s	0.739	0.59–0.88	0.004*
Fatigue ex 300°/s	0.524	0.35–0.69	0.77
H/Q ratio 60°/s	0.625	0.44–0.80	0.17
H/Q ratio 300°/s	0.544	0.36–0.72	0.62
Shoulder joint	**AUC**	**95% CI**	***P*-value**
Fatigue ER 360 °/s	0.683	0.52–0.84	0.053
Fatigue IR 360 °/s	0.352	0.19–0.51	0.12
ER/IR ratio 60°/s	0.603	0.41–0.79	0.27
ER/IR ratio 360°/s	0.432	0.24–0.62	0.47

Abbreviations: AUC, area under the curve; CI, confidence interval; ER, external rotation; H/Q, ; IR, internal rotation.

isokinetic agonist/antagonist ratio and fatigue index of shoulder IR/ER and knee flexors/extensors in male volleyball athletes. For knee joint, the results showed that previous injury influenced hamstring fatigue. These data could contribute to the implementation of a specific strengthening program earlier in the preseason for volleyball athletes who presented previous knee injuries.

Knee and shoulder injuries in volleyball players are related to long absences from sport.[2] In the present study, 22 of 49 assessed athletes (44.90%) reported a previous knee injury. Furthermore, our findings indicate that the hamstring fatigue index was associated with the presence of previous knee injuries. Additionally, this is the first study to report a cut-off point for the hamstring fatigue index. Athletes with previous knee injuries had 237% more chance to display values above 57 of fatigue index. These results demonstrated a lower capability to maintain muscle performance of knee flexors during the isokinetic test. Some authors have demonstrated an association between fatigue and alterations in knee kinetic and kinematic.[20–22] These alterations are frequently related to an increased risk of injury.[7,11,21] Knee flexors participate in open-chain knee flexion, closed chain knee extension, ground reaction force absorption during landing, and energy generation for jumping.[23,24] According to this clinical reasoning and our data, the evaluation of knee fatigue index should be included in the preseason assessment.

The H/Q ratio at 60°/s and 300°/s was not different between athletes with and without knee injury history. The injured group had a ratio of 51.75, and the non-injured group had a ratio of 50.10. Despite the difference not being statistically significant, the H/Q in the present study is lower than in other studies. Hadzic et al.[25] found a mean H/Q ratio of 61 at 60°/s in 127 volleyball players, and they reported that these values are in line with other sports. Volleyball athletes with patellar tendinopathy presented decreased hip extensors strength.[26] The hamstring contributes to this movement within the gluteus maximus, mainly during closed kinetic chain and during landing, knee extensors and hip extensors act synergistically to dissipate the ground reaction force.[27] In this sense, the presence of hamstring fatigue could increase the demand for knee extensors and predispose patellar tendon overload. Therefore, these findings reinforce the importance of strengthening knee flexor muscles during preseason.

Twenty-nine of 43 (67.44%) athletes assessed reported previous shoulder injuries. Different from what we expected, there was no association between higher fatigue index for external rotator muscles and previous shoulder injuries. Tonin et al.[28] found higher fatigability in symptomatic overhead athletes (volleyball and handball). Probably, the high fatigue index of external rotators could compromise the functional stability of the glenohumeral joint during spiking, since proper ER is necessary to avoid excessive humeral anterior translation.[29,30] The differences reported for fatigue index may indicate that our assessed athletes had better ER muscle capacity. These results could also be partially confirmed by the equalized values found for the ER/IR ratio in comparison with other studies. In this sense, sports physiotherapists and strength conditioning trainers should focus on the maintenance of appropriate shoulder ER/IR ratio during the preseason.

Similarly, the ER/IR ratios at 60°/s and 360°/s were not different between athletes with and without shoulder injury history. At 60°/s, the injured athletes had a 71.80% ratio, and the non-injured athletes had a 68.87% ratio. Stickley et al.[7] and Hadzic et al.[4] also found no statistically significant difference in the conc ER/conc IR ratio at 60°/s in female volleyball players with and without previous shoulder injuries.[7] However, in male volleyball players, the ER/IR ratio was lower on the shoulder with the previous injury in comparison with the non-injured shoulder (0.57×0.61, $p < 0.05$).[4] It is important to highlight that to prevent shoulder injury, this ratio has been reported to range from 66 to 75%.[3] In this sense, in the present study, male athletes had a proper ER/IR ratio, differently from the male athletes from Hadzic's study, which had a lower ratio. Consequently, our findings support the recommendation that is necessary to balance the strength between ER and IR, and shoulder ER strengthening must be emphasized to keep the ER/IR ratio between 60 and 75%.

This study has some limitations. The injury data was collected through self-reported questionnaires, and, therefore, memory bias could contribute to this matter. In view of this, the authors also chose to disregard information on the nature of injuries and previous rehabilitation, as these types of reports are less reliable and most prone to memory bias. Nevertheless, our results showed that previous knee injuries are associated with the hamstring fatigue index. Thus, in sports settings that do not have isokinetic tests, it could be recommended to include knee flexor resistance training for those athletes who reported knee injuries in the previous season.

Practical Applications

In the absence of isokinetic tests, we would recommend including knee flexor resistance training for those athletes who reported knee injuries in a previous season.

Conclusion

The results of the present study demonstrated an association between previous knee injury with hamstring fatigue index in male elite volleyball athletes. On the other hand, a shoulder injury in a previous season had no statistical differences on isokinetic variables on the next preseason assessment. Therefore, we recommend including the hamstring fatigue test and its specific resistance training during the preseason for athletes with previous knee injuries.

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Conflict of Interests
The authors have no conflict of interests to declare.

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