SPORTS Orthopaedics and Traumatology

ORIGINAL PAPER / SPECIAL ISSUE

Sports Orthop. Traumatol. 35, 22–30 (2019)
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www.SOTjournal.com
https://doi.org/10.1016/j.orthtr.2019.01.007

## Summary

**Background:** In the overhead sport volleyball, the glenohumeral joint is subject to repeatedly high biomechanical loading. For injury prevention, especially in adolescent players, periodic orthopaedic and biomechanical monitoring of the stabilising structures is advisable, thereby contributing to a well-balanced state of shoulder mobility and stability. The aim of the study was to examine 20 healthy male competitive junior volleyball players ($16 \pm 1$ years) to quantify sport-specific orthopaedic and biomechanical adaptations at that age.

**Material and methods:** Standard sport-orthopaedic testing was combined with overhead-specific isokinetic shoulder strength and mobility tests. The isokinetic tests were carried out in the volleyball-specific anatomic planes of external/internal rotation (ER/IR) and horizontal abduction/adduction (hAbd/hAdd) in a typical overhead posture.

**Results:** Sport-orthopaedic testing did not yield any pathological adaptations, yet revealed significant functional differences between sides ($p < 0.05$), e.g. in the hand-on-scapula-test. Isokinetic strength diagnostics showed significantly stronger internal rotators in the dominant as compared to the non-dominant shoulder ($p < 0.02$). Similarly, the ER/IR ratio was lower for the dominant shoulder ($0.9 \pm 0.2$ vs. $1.1 \pm 0.2$, $p < 0.02$). Regarding the hAbd vs. hAdd test, no lateral asymmetry was found in strength, but in mobility, where the range of motion for hAbd was significantly smaller on the dominant side ($p < 0.01$).

**Conclusions:** Mean lateral asymmetries in shoulder strength and mobility as derived in this study for healthy male adolescent volleyball players may serve as a reference of functional shoulder adaptations for future sport-orthopaedic and biomechanical shoulder diagnostics and thereby contribute to a well-balanced training control in competitive junior and junior elite sports.

**Keywords**
Isokinetic force diagnostics– Shoulder mobility– Shoulder depression and Shoulder high ;Shoulder inclination– Janda power strengths

ORIGINAL PAPER / SPECIAL ISSUE

# Physiological adaptations in the dominant and non-dominant shoulder in male competitive junior volleyball players

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Eingegangen/submitted: 02.12.2018; akzeptiert/accepted: 21.01.2019
Online verfügbar seit/Available online: 10.02.2019

## Introduction

Volleyball as a team sport with a great number of overhead strikes in training and competition implies high biomechanical loads on the joints involved, especially on the glenohumeral joint. Along with its three degrees of freedom, that particular joint is characterised by its wide range motion and the fact that it is primarily stabilised by the surrounding muscles and the capsulolabral complex [22]. A high number of volleyball-specific strikes and the accompanying high joint forces increases the risk for injuries of the secondary stabilising structures, i.e. tendons, ligaments and joint cartilage [4,5]. In many cases, those injuries can be traced back to muscular imbalances, which may result in a harmful misalignment between the humerus head (caput humeri) and the joint socket (cavitas glenoidalis), or in a dispositioned scapula [14]. The etiopathology of several related injuries has been comprehensively described before [4,5,10,12,14], including the impingement syndrome (especially in the context of a functional impingement of the supraspinatus tendon), SLAP tear (*superior labral tear from anterior to posterior*) and the SICK scapula (*scapular malposition, inferior medial border prominence, coracoid pain and malposition, and dyskinesis of scapular movement*). Functional shoulder diagnostics in elite sports generally aims at assessing the functionality of the stabilising joint muscles in the shoulder to ensure a physiologically balanced coordination of muscles and articulating bones. Typical shoulder diagnostics include sports-orthopaedic inspection, functional testing as well as mobility and strength diagnostics of the muscles involved.

For "overhead" athletes, repetitive loading can induce functional adaptations in the shoulder's surrounding muscles and structures, which may support an increased performance, but also holds potential for developing pathologic states. Some of those physiological and/or pathological adaptations can be quantified and thus can serve as predictors to estimate injury risk. The most important factors include the gain of external rotation (ER) at

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## Physiologische Anpassungen in dominanter und nicht-dominanter Schulter bei männlichen Volleyballern im Nachwuchsleistungssport


## Zusammenfassung

**Hintergrund:** Das Schultergelenk erfährt in der Rückschlagsportart Volleyball eine hohe biomechanische Belastung. Zur Verletzungsprophylaxe, insbesondere bei jugendlichen Spielern, wird daher ein regelmäßiges orthopädisches und biomechanisches Monitoring empfohlen, um die Ausprägung einer physiologischen Schulterstabilität- und -beweglichkeit zu begleiten. Ziel der vorliegenden Studie war es, auf Grundlage von 20 gesunden männlichen Nachwuchsvolleyballern (16 $\pm$ 1 Jahre) die bereits in diesem Alter vorliegenden sportartspezifischen orthopädischen und biomechanischen Anpassungen zu objektivieren.

**Materialien und Methoden:** Es erfolgte eine kombinierte Untersuchung, bestehend aus sportorthopädischen Standardtests für das Schultergelenk und mehreren spezifisch für Überkopfsportarten entwickelten isokinetischen Kraft- und Beweglichkeitstests. Die isokinetische Diagnostik wurde dabei in den volleyballrelevanten anatomischen Ebenen der Außen- und Innenrotation (AR/IR) sowie der horizontalen Abduktion/Adduktion (hAbd/hAdd) in einer sportartspezifischen Schlaghaltung durchgeführt.

**Ergebnisse:** Im Ergebnis der sportorthopädischen Standradtests zeigten sich keine Symptome pathologischer Anpassungen im Schultergelenk, wenngleich sich signifikante funktionelle Seitigkeitsunterschiede z. B. bei dem Hand-auf-Scapula-Test ergaben ($p < 0{,}05$). Die isokinetischen Untersuchungen belegten signifikant stärkere Innenrotatoren in der dominanten Schulter im Vergleich zur nicht-dominanten ($p < 0.02$); entsprechend geringer fiel das AR/IR-Verhältnis für die dominante Seite aus (0,9 $\pm$ 0,2 vs. 1,1 $\pm$ 0,2, $p < 0{,}02$). Hinsichtlich hAbd


the dominant side, expressed as disparity between the dominant and non-dominant shoulder [2,3,14,20,23], and the muscular agonist-antagonist ratio in the dominant shoulder [8,18,21,22]. Assessing those quantities, athletes with higher and lower risk for shoulder injury can be identified. For instance, beyond a lateral discrepancy of 20° in shoulder mobility, an increased injury risk is observed [14], as it is for an agonist-antagonist strength ratio lower than 50%, i.e. a strength ratio between external vs. internal rotators, or horizontal abductors vs. horizontal adductors.

The purpose of this study was to examine shoulder mobility and strength capabilities of 20 healthy competitive junior volleyball players in preseason for deriving ranges and mean values of physiological asymmetries resulting from functional adaptations, and not being affected by injury. Those values may serve as a first reference for future orthopaedic and biomechanical diagnostics of adolescent volleyball players, and possibly of overhead athletes from further disciplines, for estimating the individual injury risk and thereby being able to adapt training structure and intensity. For this purpose, we combined sport-orthopaedic inspections with functional tests as well as biomechanical mobility and strength diagnostics and analysed the results in that common context.

## Methods

### Subjects

Twenty male junior volleyball players (15.7 $\pm$ 0.8 years of age, body mass 79.2 $\pm$ 10.1 kg, body height 1.90 $\pm$ 0.04 m) underwent a sport-orthopaedic inspection and performed a set of shoulder strength and mobility tests. All participating players were members of the regional elite squad with a training history of 3–4 years and at least 20 h of training per week. All participants were healthy at the time of testing and did not report any acute injuries.

### Sport-orthopaedic inspection

The sport-orthopaedic inspection comprised the screening of posture and functional movement patterns encompassing the whole body, aiming at detecting any musculoskeletal imbalances [6,7,15,16]. The posture screening focused on the spine (scoliosis, lordosis etc.), the limbs (length and static discrepancy), shoulder tilt and pelvic tilt. The assessment of functional movement patterns included rotary stability and flexibility tests of the main muscle groups and the examination of glenohumeral mobility and strength capabilities, such as hand-to-scapula-test (testing the range of internal rotation with adducted upper arm), the empty-can-test (focused on the supraspinatus muscle). Gerber's lift-off-test (focused on the subscapularis muscle) and Yergasons test (focused on the long biceps tendon). Standardised scoring criteria and categories of muscle strength and flexibility, e.g. test of tightness in the pectoralis major and minor muscles, were applied, following the manual of Janda [9]: 5: *normal* (approximately 100% of physiological strength level), 4: *good* (75%), 3: *fair* (50%), 2: *poor* (25%), 1: *trace* (10%), 0: *zero* (0%).

### Strength and mobility diagnostics

After the sport-orthopaedic examination confirming that the player was able to finish the subsequent tests, each player passed a standardised warm-up period of 15 min, focusing

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und hAdd konnte keine laterale Asymmetrie in den Kraftvoraussetzungen festgestellt werden. Es zeigte sich jedoch eine laterale Diskrepanz in der Beweglichkeit, die sich in einem signifikant verringerten Bewegungsumfang der dominanten Schulter in der hAbd äußerte ($p < 0.01$).

**Schlussfolgerungen:** Die ermittelten Orientierungswerte für laterale Asymmetrien in Kraft und Beweglichkeit des Schultergelenks, wie sie in dieser Studie für jugendliche Volleyballspieler abgeleitet worden sind, könnten zukünftig als Referenz für funktionelle Anpassungen im Rahmen von sportorthopädischer und biomechanischer Diagnostik herangezogen werden und auf diese Weise zu einer ausgewogenen Trainingssteuerung im Nachwuchsleistungssport-Volleyball beitragen.

**Schlüsselwörter**
Isokinetische Kraftdiagnostik – Schulterbeweglichkeit – Schultertiefstand und Schulterhochstand – Schulterschiefstand – Kraftgrade nach Janda

on the shoulder girdle. Subsequently, several tests on strength and mobility were carried out using an isokinetic dynamometer (*IsoMed 2000*, D&R Ferstl GmbH, Hemau, Germany), operated by the same two experienced researchers. The two prominent anatomic planes of shoulder motion in overhead activities were studied, starting with external rotation vs. internal rotation (ER/IR) and followed by horizontal abduction vs. horizontal adduction (hAbd/hAdd, Fig. 1). All tests were carried out in supine position, mimicking a typical overhead posture characterised by 90° shoulder abduction and 90° elbow flexion (Fig. 1). As for ER/IR testing, the humerus was aligned parallel to the rotational axis of the dynamometer (Fig. 1, left). The range of motion (ROM) spanned 120°, comprising joint angles in the sagittal plane from +10° to −110°, where 0° denotes the neutral joint position corresponding to an upright standing posture with the extended, non-abducted arms loosely aligned along the trunk. For hAbd/hAdd testing, the ROM spanned 110° from +10° to −100°, with the rotational axis aligned pointing at the acromion. All obtained torques in strength and mobility testing were adjusted for gravity by employing an integrated compensation routine for apparatus weight (ER/IR-testing) and apparatus as well as arm weight (hAbd/hAdd-testing), respectively. The adequacy of the test-retest reliability for the mobility and isokinetic strength test parameter has been verified before, yielding an intra class correlation coefficient of $ICC = 0.68–0.96$ [17].

The individual testing started with strength measurements, which were all performed in concentric fashion at the two distinct angular velocities of 60°/s and 180°/s. The athlete was instructed to support the dynamometer's motion with maximum voluntary effort and to take a break of rest at the end of each motion for at least one second. After four to six initial submaximal trials for familiarisation and specific warm-up, three maximal trials were performed and recorded consecutively in alternating direction as a time series of applied torque. The strength test was followed by the mobility test, whereby the strength trials contributed to standardisation of test conditions. Mobility was passively measured for ER and hAbd with the upper and lower arm fixed to the apparatus as for strength testing, cf. Fig. 1. For ER, a wrist stabiliser was used to restrict dorsal flexion in the wrist, ensuring isolated shoulder rotation. The participants were instructed to stay entirely relaxed while the dynamometer moved slowly at 15°/s in the pertinent direction. By that motion, the antagonistic structures of ER (i.e. the internal rotators, including the subscapularis, the pectoralis major and the coracobrachialis) and of hAbd (i.e. the horizontal adductors, including the pectoralis major, the coracobrachialis and the deltoideus) around the glenohumeral joint were slightly stretched. The dynamometer movement immediately stopped when a passive restoring torque of 16 N m was reached, yielding the maximum angular deflection of that bout and thus providing mobility in terms of joint ROM. The threshold of 16 N m was derived in a pilot study as a sufficient compromise between participant compliance (in avoiding active muscular counter-movement reflexes for protection) and reliability (by inducing appropriately high angular deflections). For additional safety, the maximum ROM was limited to 130° from neutral position. After a familiarisation of two to four trials, five tests were performed.

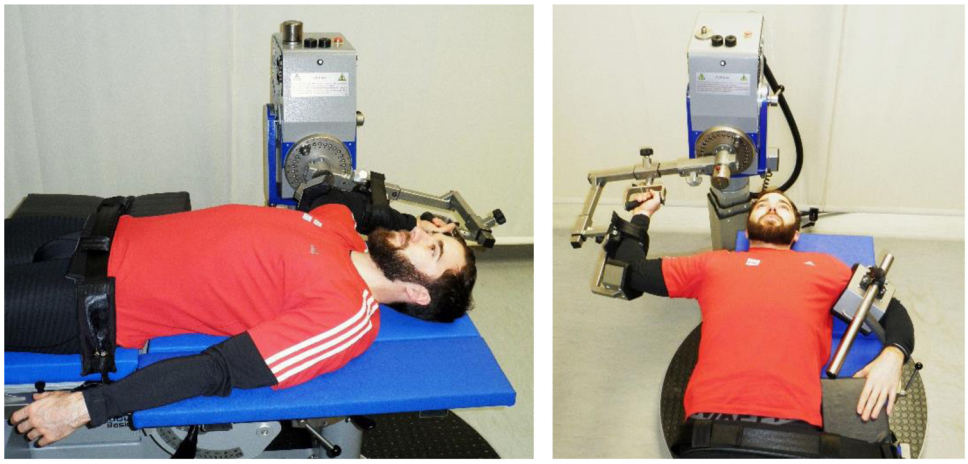

Figure 1
**Strength and mobility testing. Left: External rotation vs. internal rotation (depicted: external rotation of 120°), Right: Horizontal abduction vs. horizontal adduction (depicted: 100° abducted) as measured with the contralateral upper arm fixed.**

### Data analysis and statistics

Concerning strength capabilities, peak torque values were extracted from the isokinetic phase of the acquired time series, reflecting the maximum force that could be generated by the acting muscle groups under the given conditions during that bout. The median of the three peak values was used for further data analysis. As for mobility, the mean of the obtained five maximum angular deflections was calculated. The dominant shoulder was defined by the preferred handedness of volleyball-specific strikes as reported by the athlete. Lateral asymmetry $\Delta$ in strength was defined as the difference of peak torques of the dominant ($D$) and non-dominant shoulder ($N$) divided by the mean of both sides, i.e.

$$\Delta := 2\frac{D-N}{D+N}\cdot 100\%$$

Hence, $\Delta > 0\%$ indicates a greater torque in the dominant shoulder, whereas $\Delta > 0\%$ corresponds to a stronger non-dominant shoulder. For mobility, the lateral discrepancy was defined as the difference between the maximum angular deflexions of the dominant and the non-dominant shoulder, i.e. $D - N$ measured in degrees.

All statistical calculations were performed using SPSS version 23.0 (SPSS, Inc., Chicago, IL, USA). Normal distributions for all raised metric parameters were confirmed by Kolmogorov-Smirnov tests. Statistical significance of mean differences in metric variables was confirmed by Student's $t$ test. For interval-scaled parameters, like sport-orthopaedic inspection scores, the Wilcoxon signed-rank test was performed instead. Fisher's exact test was employed for assessing relations between mixed-type variables, e.g. for sport-orthopaedic scores vs. strength and mobility maximum values. Standard level of significance was set to $p < 0.05$.

## Results

### Sport-orthopaedic inspection and functional screening

During anamnesis, all subjects declared freedom from acute injuries. The sport-orthopaedic inspection confirmed that 19 out of 20 subjects exhibited functional, i.e. non-pathological, adaptations in their shoulder joints. Although one athlete showed symptoms of a functional impingement syndrome of the supraspinatus tendon in the dominant shoulder, he insisted on being free of symptoms. An *obliquity of the dominant shoulder* was identified for 75% of the athletes (15/20). There was no link to any considerable scoliosis, limb length discrepancy or pelvic tilt, even though some athletes exhibited a habitual scoliotic posture. In contrast, one athlete showed an elevated dominant shoulder due to a tight levator scapulae muscle. The *hand-on-scapula* test revealed significant differences between the non-dominant and dominant shoulder, with a reduced range of IR for the dominant side (Table 1). The *empty-can test* revealed for 75% (15/20) of the subjects a strength level of 5 on the Janda scale for both the dominant and the non-dominant shoulder, confirming normal strength of the supraspinatus muscle. The other 25% (5/20) achieved at least a level of 4-. No

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**Table 1.** Hand-on-scapula test: Number of subjects per category.

| | Infrascapular | Scapular | Suprascapular |
|---|---|---|---|
| Non-dominant | 1 | 5 | 14 |
| Dominant | 5 | 15 | 0 |

Infrascapular: Subject is not able to reach the scapula (angulus inferior) with his second metacarpal.
Scapular: Subject reaches angulus inferior of the scapula.
Suprascapular: Subject "over-reaches" angulus inferior of the scapula.

significant lateral asymmetry was observed. Testing strength and functionality of the subscapularis muscle in the *lift-off test*, all subjects achieved the highest level of 5 on their non-dominant side. For the dominant side, 85% (17/20) exhibited level 5, the other 15% (3/20) at least level 4-. Furthermore, the Yergason test yielded level 5 for both shoulders in all athletes (20/20), confirming normal functionality for the long head of the biceps muscle and its tendon. An inspection of mobility in the horizontal abduction/adduction-plane revealed that 30% (6/20) were subject to a non-pathological reduced ROM for abduction in the dominant shoulder, resulting in a significant difference between sides.

## Isokinetic strength tests

For all tested muscle groups in both shoulders, a significant negative relation between strength capability and contraction speed is observed, as expected from Hill muscle dynamics.

### *External and internal rotation*

Regarding peak torques in ER and IR (Fig. 2), the internal rotators of the dominant shoulder are found to be significantly stronger than those of the non-dominant side at both tested speeds. Mean lateral asymmetries amounted to +12% at 60°/s ($35 \pm 8$ N m vs. $31 \pm 7$ N m) and +15% ($33 \pm 9$ N m vs. $28 \pm 7$ N m) at 180°/s, respectively. For the external rotators, no significant lateral differences were observed. Hence, the resulting agonist-antagonist peak torque ratios $R_{ER/IR}$ are significantly greater for the non-dominant vs. the dominant side at both 60°/s ($1.09 \pm 0.16$ vs. $0.93 \pm 0.11$) and 180°/s ($1.03 \pm 0.13$ vs. 0.89 + 0.19).

### *Horizontal abduction and adduction*

As for horizontal abductors and adductors, achieved mean peak torques were significantly higher for the dominant shoulder at both speeds, yet with only small effect size (Fig. 3). Lateral asymmetry amounted to 3–8%. While the resulting agonist-antagonist peak torque ratios $R_{hAbd/hAdd}$ are insignificantly greater for the non-dominant side at 60°/s ($1.02 \pm 0.17$ vs. $0.98 \pm 0.19$), they are significantly lower as compared to the dominant side at 180°/s ($0.87 \pm 0.24$ vs. $0.89 \pm 0.20$). Hence, no general lateral asymmetry could be identified for hAbd/hAdd.

## Mobility tests

In the passive mobility test for external rotation and horizontal abduction, we found substantial inter-subject variability in ROM with values ranging between 116–160° for ER and 108–161° for hAbd (Table 2). In general, the dominant shoulder exhibited a slightly wider ROM for ER ($135 \pm 9°$ vs. $131 \pm 10°$) but smaller ROM for hAbd ($128 \pm 11°$ vs. $135 \pm 10°$) as compared to the non-dominant shoulder. The corresponding mean pairwise difference in lateral mobility is non-significant for ER ($+4 \pm 10°$), but significant for hAbd ($-7 \pm 7°$). It is to be noted, however, that in contrast to intra-individual side-by-side comparisons, inter-individual mean values of ROM may be affected by individual differences in muscle and tissue volume, so that a certain anthropometric bias may be present in the obtained mean values. As the group of subjects studied was homogeneous in age and general constitution, that bias is presumably small, though.

## Discussion

Apparently, adaptations in the dominant "hitting" shoulder of the junior volleyball players had already taken place, even though they had experienced only a limited number of years of sport-specific training so far. The most evident findings were observable in the strength capabilities of the internal rotators, which significantly differed between the non-dominant and the dominant shoulder: The internal rotators exhibited significantly higher peak torques in the dominant than in the non-dominant shoulder, whereas the external rotators were well-balanced between sides. This, in turn, resulted in a decrease of the

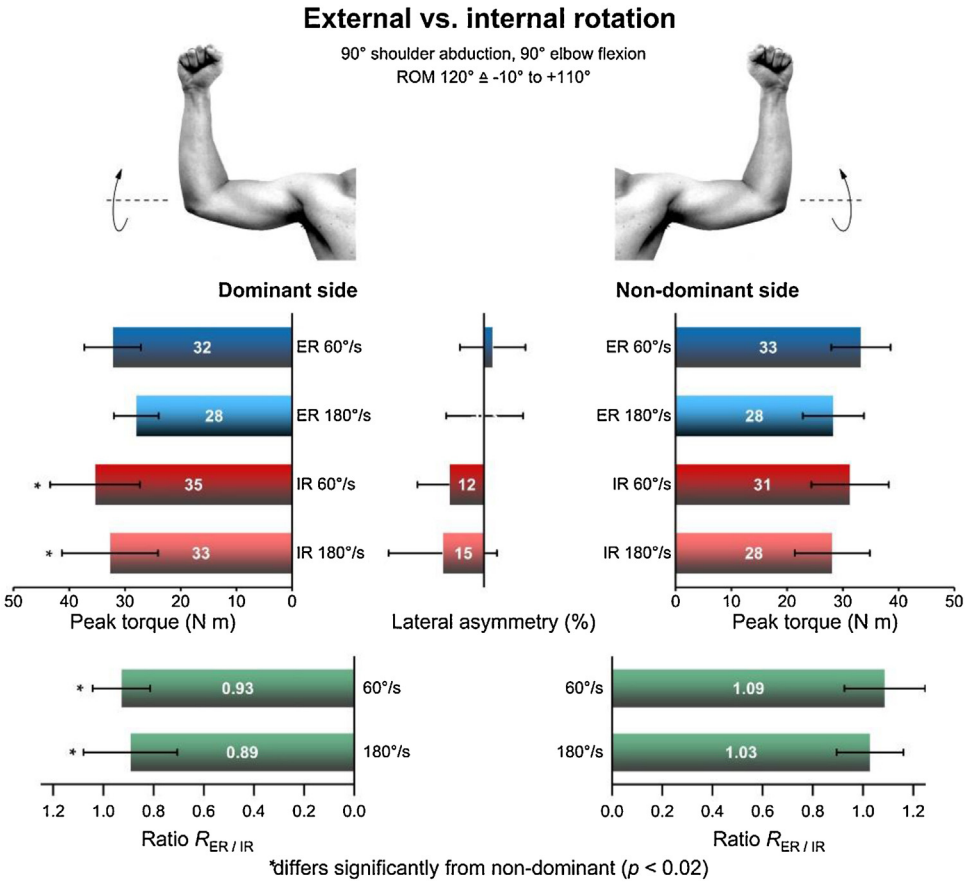


Figure 2
**Peak torques and agonist-antagonist ratios for external and internal shoulder rotation.**

concentric ER/IR ratio $R_{ER/IR}$ for the dominant shoulder, yielding a lateral asymmetry of +15%. That finding is in accordance with previous studies [8,13,22], while absolute peak torques cannot be compared because of differing subject cohorts and methods used. In summary, the mean ER/IR ratios as found in our study, i.e. $R_{ER/IR} = 0.9 \pm 0.2$ and $R_{ER/IR} = 1.1 \pm 0.2$ for the dominant and the non-dominant shoulder, respectively, seem to be functional and thus should not be considered a predictor for an increased injury risk due to imbalanced agonist-antagonist muscle groups.

Regarding mobility of the ER/IR muscle group, further signs of adaptation were observed. In the test of passive mobility of the IR muscles and their tendinous components, as carried out on the dynamometer, a non-significant tendency to a greater ROM in external rotation was found. The corresponding mobility during the functional screening revealed a significant deficit in IR for the dominant shoulder. Moreover, there was a significant negative correlation between the external rotation ROM as measured in the mobility test on the dynamometer and the internal rotation ROM as obtained during functional screening. In particular, those athletes who had achieved a high level of passive ER showed a low level in the hand-on-scapula-test for IR and vice versa. That finding confirms, to some extent, the concept described in Pieper et al. [14], according to which the ROM of ER and IR between sides remains constant, while a gain in ER causes a deficit in IR due to physiological adaptations.

In summary, the results of the sport-orthopaedic inspection suggest that the observed adaptations, like an obliquity of the dominant shoulder or a lateral asymmetry in the hand-on-scapula-test, are physiological and do not imply a higher injury risk. Furthermore, the functional movement screening confirmed a normal, functional status of all tested muscle groups of all but one athletes, ensuring physiological movement patterns of scapula and humerus. Interestingly, regarding

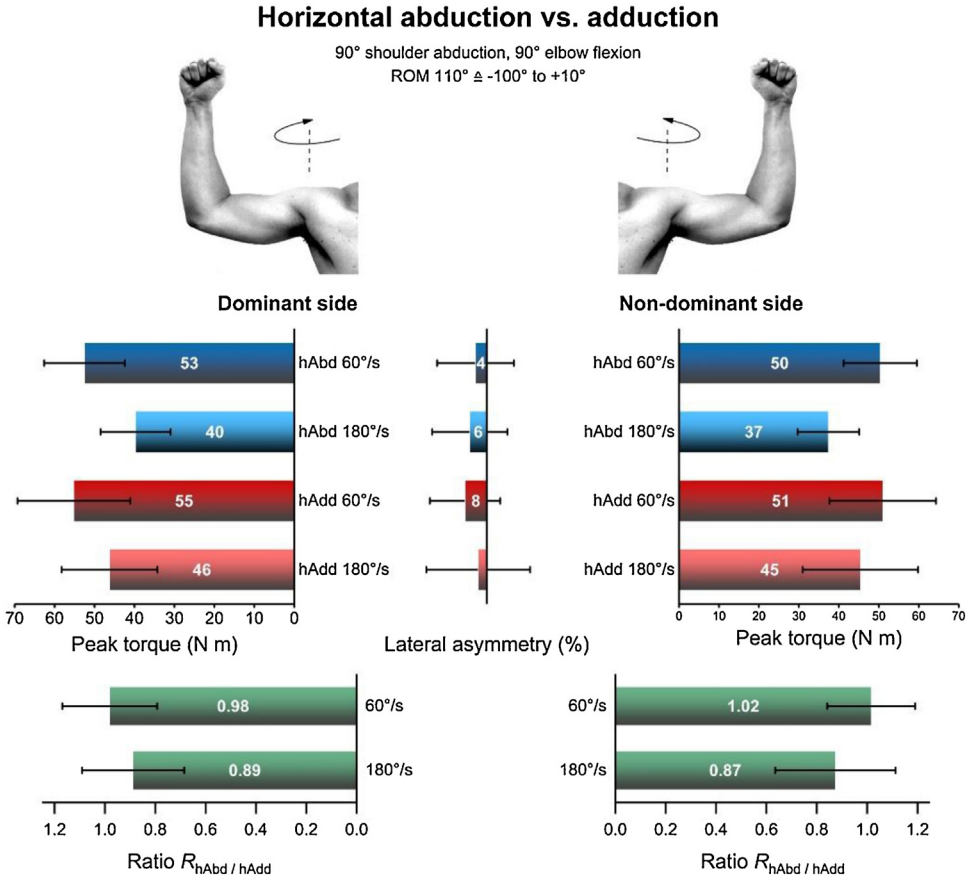


Figure 3
**Peak torques and agonist-antagonist ratios for horizontal abduction and adduction.**

the only exception, where one athlete exhibited (thus far unknown) symptoms of an impingement syndrome, external rotators strength and accompanying ER/IR ratios in the dominant-side (0.82 and 0.68, for 60°/s and 180°/s respectively) were far below both the group average and his non-dominant shoulder (1.02 and 0.92, respectively). Similarly, he exhibited a gain of 16° in passive ER for the dominant shoulder as compared to the non-dominant side, further supporting the hypothesis of a deficiency in ER strength. Nonetheless, the observed lateral discrepancy in ROM of 16° was still below the above-mentioned threshold of 20° for an increased injury risk. Whether this is cause or effect cannot be concluded at this point.

Regarding horizontal abduction and adduction as examined during the dynamometer test (cf. Fig. 3), we found on average a well-balanced and laterally symmetric muscular

**Table 2.** Passive mobility range of motion for external rotation and horizontal abduction.

| | Dominant | | Non-dominant | | Discrepancy | Significance |
|---|---|---|---|---|---|---|
| *ROM* | Mean ± SD | Min–Max | Mean ± SD | Min–Max | Mean ± SD | *p* value |
| ER (°) | 135 ± 9 | 116–158 | 131 ± 10 | 117–160 | +4 ± 10 | n.s. |
| hAbd (°) | 128 ± 11 | 108–161 | 135 ± 10 | 118–159 | −7 ± 7 | 0.000 |

constitution, despite slightly higher strength capabilities of the dominant side. To the best of our knowledge, there are only a few studies addressing dynamometric horizontal abduction/adduction strength testing. Silva et al. [19] tested healthy young tennis players (male and female, aged 12 to 18), and therefore matches to some degree our subject cohort and study design. Concerning lateral asymmetry, which is least affected by the methods used, is reported to be about +5%, which is comparable to our findings. A similar study of Alderink and Kuck [1], who examined baseball pitchers (aged 14 to 21) without shoulder pathology, found no lateral asymmetry and almost even ratios $R_{hAbd/hAdd}$, being in accordance to our results. Surprisingly, the pectoralis major muscle, which strongly contributes to overhead activities in volleyball, apparently does not adapt to highly repeated one-handed hitting in terms of a strength gain. However, the sport-orthopaedic inspection revealed a significantly reduced mobility in hAbd for the dominant side, which is confirmed by the results of the passive mobility test on the dynamometer, where a significant deficit of 7° was observed in the dominant as compared to the non-dominant shoulder (see Table 2). It is conceivable that hypertonicity is responsible for that effect.

## Conclusions

The shoulder is a frequently used and highly loaded joint in the context of competitive overhead sports like volleyball. It is actively "forced" into anterior elevation with adduction and internal rotation during attack, serve and pass. When blocking an attack of the opponent team, in contrast, it is moved into retroversion, thereby inducing eccentric loading on the involved muscle-tendon complexes. As a result of high shoulder loading in overhead sports, sport-specific imbalances may develop. In spite of that, 95% (19 out of 20) of the examined young athletes did not exhibit any morbidity of their shoulder joints (while the only athlete with a relevant diagnosis exhibited an unnoticed functional impingement syndrome). Therefore, our results suggest that the studied cohort of competitive junior athletes had been well conditioned for the experienced biomechanical loading in training and competition, including specific strength training. However, there are indications for sports-specific, training-induced muscular asymmetries in the muscular constitution of the adolescent athletes, which already affect body posture. Thus, long-term follow-up examinations of these athletes are recommended to further elucidate the relation of functional adaptations and pathological overuse symptoms of the shoulder joint, as commonly seen in mature volleyball players [11]. In order to reduce the risk of shoulder injuries and pathological adaptations of the musculoskeletal system in adolescents in general, but also to document physiological adaptations, a biomechanical and sports-orthopaedic examination is recommended at least once a year for competitive junior volleyball players.

## Conflict of interest

There is no conflict of interest.

## Acknowledgements

We thank Mr. Stefan Ehrlicher for his committed support in the isokinetic strength and mobility tests.

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