DOI 10.26773/smj.211012

SportMont

REVIEW PAPER

Occurrence of Muscle Imbalance and Risk of Injuries in Athletes using Overhead Movements: A Systematic Review

Tengku Fadilah Tengku Kamalden[1], Qais Gasibat[1], Shamsulariffin Samsudin[1] and Jacklyn Anak Joseph[1]

[1]University Putra Malaysia, Department of Sport Studies, Kuala Lumpur, Malaysia

Abstract

The purpose of this study was to examine injuries attributed to muscle imbalance in sports with overhead movements. Available sources in the period between 2010 and 2020 that provide an overview of the occurrence of muscle imbalance and the risk of injuries in overhead sports were evaluated. A comprehensive search of relevant sources was conducted using Google Scholar, PubMed databases, and other databases, including Science Direct, Research Gate, Web of Science, and Psyc Info. Eleven articles met the criteria to be included in the systematic review. Muscle imbalance significantly impacted overhead athletes and was responsible for injuries of the shoulder, lower back, elbow, and wrist. Based on the findings of the review, further study on muscle imbalance should be carried out. More importantly, future research should investigate the muscle imbalance in the non-dominant side and identify relevant exercises that can reduce the imbalance and increase the stability and strength of the muscles on the non-dominant side. Researchers have identified muscle imbalance as a cause of the injuries, but detailed information on the prevalence of muscle imbalance and its impact on athletes remains lacking.

Keywords: *dominant and non-dominant limbs, overhead sports, injuries, muscle imbalance*

Introduction

Researchers have identified numerous overhead sports, including water polo (Lupo, Capranica, Cugliari, Gomez, & Tessitore, 2016), tennis (Correia, Oliveira, Vaz, Silva, & Pezarat-Correia, 2016; Trompeter, Fett, & Platen, 2017), rowing (Bahr et al., 2004), wrestling, and weightlifting (Baranto, Hellström, Cederlund, Nyman, & Swärd, 2009), golf and baseball (Lee, Tuite, & Rosas, 2010), gymnastics (Parikh, Case, Hogarth, & Abzug, 2020), badminton, basketball, handball (Kaplan, 2016), tracking, shooting, swimming, volleyball, karate, and futsal (Noormohammadpour et al., 2016). These sports usually require a player to apply a throwing technique or movement that involves shoulder and upper arm action above their head at one point or the other in the game. The athletes must also coordinate their movements in a kinetic chain from the feet to their hands (Kibler, 1998).

The execution of skills during competition and training requires the overhead athletes to perform multiple times within that period, whether it is acute or chronic. Hence the likeliness of developing a stronger side of the body is very evident. This is especially true for athletes or players in one-sided games, such as squash, badminton, and water polo. Unfortunately, this leads to muscle imbalance (Kraan et al., 2019), which has been linked to the occurrence of injuries as it substantially increases the risk due to the differences in strength, and this is directly correlated with the reduced performance of the athletes (Page, Frank, & Lardner, 2011).

Various training has been suggested to improve performance, but the mechanics applied by athletes, including shoulder elevation, increase the risk of injuries (Edmonds & Dengerink, 2014). The risks of overhead injuries are attributable to the distinct mechanics applied in the shoulder region,

Correspondence:

Q. Gasibat
University Putra Malaysia, Department of Sport Studies, 43000, Serdang, Selangor, Kuala Lumpur, Malaysia
E-mail: drqaiss9@gmail.com

including external rotation, abduction, and elevation. In addition, injuries may result from muscle imbalance, making the athletes prone to weakness in the shoulder and elbow (Noguchi, Demura, Takahashi, Demura, & Mori, 2014).

A well-structured rehabilitation programme is useful in the treatment of overhead sports injuries attributed to muscle imbalance. The biomechanics and frequencies of how the athletes use their body parts in the overhead sports determine injury patterns (Murray, Goudie, Petrigliano, & Robinson, 2013). For example, injuries to the upper limbs of athletes in overhead sports may vary depending on the specific aspects of that sport.

Most Common Injuries in Overhead Sports

Overhead athletes are susceptible to a significant number of injuries, with 18.3% and 21.4% upper extremity damages occurring during game and practice, respectively (Hootman, Dick, & Agel, 2007). Researchers argue that the majority of the injuries in overhead sports are a result of reduced training sessions. Koh and Dietz (2005) reported that a temporary reduction in sports activities increases the risks of injury when the players resume their schedule. However, some of the players maintain their training despite being in pain, thus increasing their risk of suffering injuries while attempting to improve performance. In addition, in overhead sports, athletes are expected to coordinate their movement at the shoulder, wrist, and elbow joints (Escamilla, Fleisig, Barrentine, Zheng, & Andrews, 1998; Fleisig et al., 1996). Therefore, during training or game competitions, the players tend to overuse the upper limbs, thus increasing the risk of joint disorders in the shoulder and elbow.

Studies have discovered injuries to the shoulder as a common occurrence among overhead sport athletes (Fahlstrom & Soderman, 2007). Shoulder pain is more common among badminton players. Shoulder pain is recognized as one of the most frequent injuries that affect female and male athletes. Nearly 30% of the overheard sports athletes suffer a shoulder injury in their careers (Laudner & Sipes, 2009). Researchers also reported injury prevalence of approximately 34.7% to 66.7% in swimming and diving, respectively (Roos et al., 2015). Athletes are at risk of developing chronic conditions as they continue engaging in sports despite the pain. Studies have suggested that limited muscle strength increases the risk of shoulder injuries in overhead sports (Pennock et al., 2018; Atan, Yüceloğlu Keskin, Çamlidağ, & Derebaşi, 2019). Moreover, the excessive range of motion applied to the shoulder also contributes to shoulder pathology among overhead athletes.

The increased popularity of overhead sports, such as baseball, tennis, and golf, has led to a rise in the number of people participating in sports activities (Wilk et al., 2009). Moreover, almost one in every four members of a family participates in these sports; therefore, hospitals and other health facilities are attending to more patients with elbow injuries (Wright, Hegedus, Tarara, Ray, & Dischiavi, 2018). Lee, Tuite and Rosas (2010) claimed that although injuries vary between adults and children, the risk factors are similar, including deconditioned state, suboptimal mechanics, and improper equipment. Equally, the biomechanical demands placed on the athlete's elbow during upper extremity activities increase the risk of joint disorder (Zellner & May, 2013; Lam & Siow, 2012).

Parikh et al. (2020) also mentioned the so-called gymnast wrist as one of the injuries attributed to overhead sports. Excessive weight-bearing activities in the upper extremity result in a chronic wrist condition properly known as radial epiphysitis. Wrist injuries are commonly observed in gymnasts since they exert extreme pressure on the vulnerable region of the wrist. Moreover, tennis players are also susceptible to distinct wrist pathologies due to the stress fractures attributed to ulnar impaction and damages to the triangular fibrocartilage (Gil & Kakar, 2019). In addition, players may experience posterosuperior labral tears, supraspinatus avulsions, and scapular dyskinesis. Thus, the majority of these athletes are susceptible to various injuries, including in the elbow, wrist, and shoulder (Putty, 2010), Low Back Pain (LBP), and because of the excessive force and stress applied during the activity of throwing or playing the overhead sports (Wilk et al., 2015).

Incidence of Muscle Imbalance

Overhead sports are closely related to injuries caused by a muscle imbalance in the elbow, wrist, shoulder, and lower back regions. In addition, muscle imbalance exposes athletes to an increased risk of joint disorders (Noguchi et al., 2014). Researchers have discovered that the alterations in muscle imbalance and flexibility are common among overhead athletes (Burkhart, Morgan, & Kibler, 2003), and hence proper balance to an athlete's muscles is crucial for flexibility and stability in preventing potential injuries in the shoulder region. Athletes rely on muscles in distinct regions, such as the shoulder (Page et al., 2011), to enhance muscle performance during different motions and mobility in sports activities. However, muscle imbalances result in movement impairments due to changes in arthrokinematics, which may cause structural damages. Page (2011) claimed a deficit in the strength or flexibility in one muscle, such as an agonist, has to be compensated by another muscle, which in this case, is the antagonist muscle, thus leading to a dysfunction. Wang, Macfarlane and Cochrane (2000) also related muscle imbalance to isokinetic muscle strength, whereby musculoskeletal discomfort, pain, and weaknesses in the shoulder regions are attributed to concentric and eccentric contractions on the dominant and non-dominant shoulders of athletes.

According to Page, Frank and Lardner (2011), muscle imbalance is attributable to weaknesses in different regions of the upper limb, including the lower and middle trapezius, infraspinatus, deltoid, serratus anterior, and when coupled with the tightness of levator scapula, upper trapezius, and pectorals, it increases the risk of structural damage for the athletes. Lin, Wu, Wang and Chen (2005) argued that increased activities in the trapezius muscle could result in substitution in scapular movement as compensation for the glenohumeral motion impairment. Athletes may be required to apply abnormal scapular motion, including increased upward rotation and excess elevation of the scapula (Challoumas, Artemiou, & Dimitrakakis, 2017). The players should understand that abnormal scapular motion causes imbalances in muscle activity. The imbalances can occur due to upward rotation and elevation of the scapula by the upper trapezius coupled with the contraction of the lower trapezius to maintain the equilibrium of the scapula (Wright et al., 2018).

Studies have also discovered a positive relationship between isokinetic evaluations and muscle imbalance. In sports in which athletes are expected to exercise overarm throwing, cases of imbalances in muscle strength have been identified in relation to isokinetic evaluations (Codine, 1997; Edouard, Damotte, Lance, Degache, & Calmels, 2013; Andrade et al., 2010). While exercising a throwing technique, athletes are expected to apply concentric and eccentric contractions (Olivier & Daussin, 2019). Although the concentric action influences the throwing velocity,

the eccentric contraction acts as a break limiting an increase in distraction force experienced in the upper limb (Sirota, Malanga, Eischen, & Laskowski, 1997). The use of a mixed ratio in internal and external rotators by concentric and eccentric actions increases the risk of shoulder imbalance, resulting in injuries.

Wang, Macfarlane and Cochrane (2000) argued that overhead sports such as volleyball, tennis, swimming, and javelin throwing require players to engage in repetitive forceful arm actions. The actions in these sports place an excessive eccentric load on the rotator cuff muscles of an athlete's shoulder, thus exposing them to injury. Therefore, an injured rotator cuff muscle is more likely to lose the capacity to maintain stability with the antagonist, and as a result of the imbalance in the shoulder region, an athlete is at increased risk of shoulder impingement. Moreover, Nekooei et al. (2019) argued that the majority of the overhead throwers face a similar problem, which involves an imbalance in the shoulder movement strength. Minimal internal or external glenohumeral rotations may cause injuries such as shoulder and LBP, and hence have a negative effect on the performance of athletes.

Researchers have identified differences in dominant and non-dominant sides of overhead athletes that are also responsible for potential injuries. The dominant shoulder of an overhead athlete is different from the non-dominant in terms of strength, morphology, muscular balance, and range of motion (Borsa, Laudner, & Sauers, 2008). Some of the sports activities may require the players to rotate the dominant arm at the maximum position while attempting to maintain a balance and level of accuracy. In volleyball, for instance, players try to produce high velocity and large forces on their arms by rotating the dominant shoulder; although they may achieve the expected results of accuracy, they end up being exposed to injuries attributed to muscular imbalance. In water polo, an overhead sport that exposes athletes to a number of injuries, especially to the shoulder region, players are expected to exhibit higher work in eccentric and concentric action and display high muscle endurance performance. Olivier and Daussin (2019) argued that the dominant shoulder of most water polo players tends to be stronger than their non-dominant shoulder. This imbalance increases the risk of injury to the shoulder region of an athlete participating in water polo.

Athletes are likely to suffer injuries attributed to muscle imbalance because of the different muscle forces applied in the dominant and non-dominant arm. The dominant arm applies muscle force nearly 10% greater than the non-dominant arm (Betchol, 1954; Gedela, Kirby, & Huhtala, 2008). Zuzgina and Wdowski (2019) considered the asymmetric nature of movements of an athlete's shoulder as a crucial cause of strength imbalances. Volleyball players are exposed to asymmetries between their dominant and non-dominant sides. However, other than the strength imbalances attributed to dominant and non-dominant shoulders, external and internal rotators play a crucial role in stabilizing the glenohumeral joint, and the failure to achieve a balance results in injuries.

The present systematic review looks into the occurrence of muscle imbalance and the risk of injuries linked to it, as well as the recommendation by the research.

Methods

The present study conducted a literature search for potential articles on databases such as PubMed, PsycInfo, ScienceDirect, and on the internet using Google Scholar. An additional search was carried out on the following databases ResearchGate and Web of Science. Keywords used to perform the search include muscle imbalance, overhead sports, dominant and non-dominant sides, and injuries. Database and internet searches centred on articles and papers within the period from 2010 to 2020. After identifying the potential papers and articles, screening of abstracts and full-text was carried out to select sources that would be assessed for eligibility using the "Strengthening the Reporting of Observational Studies in Epidemiology." Eligibility of the sources would help examine potential bias in the study. Relevant studies that passed the eligibility test were included in the review, as shown in Figures 1 and 2.

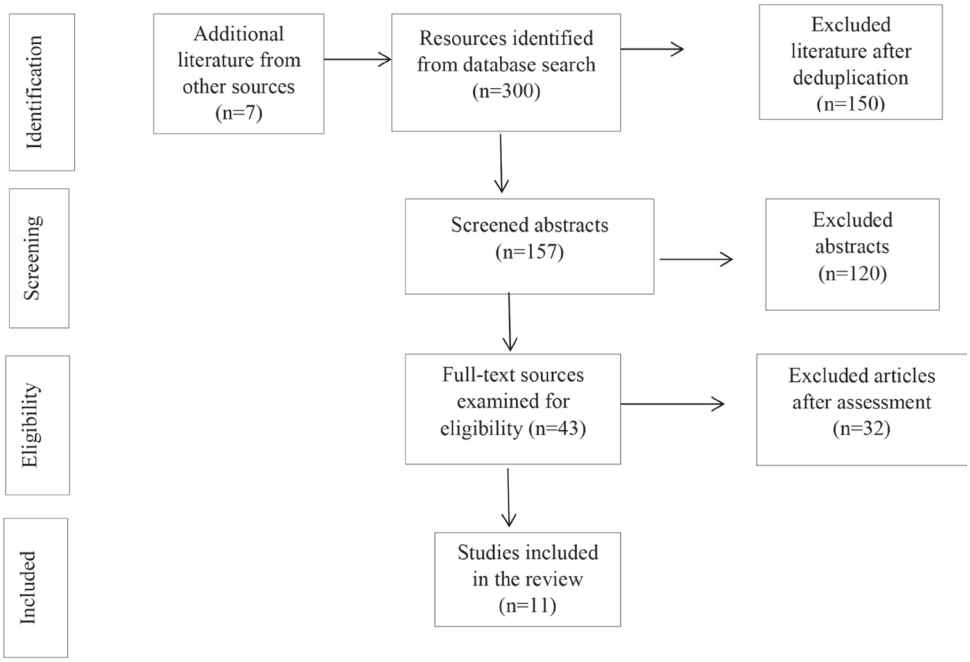

FIGURE 1. Preferred reporting items for systematic reviews flow diagram of included studies

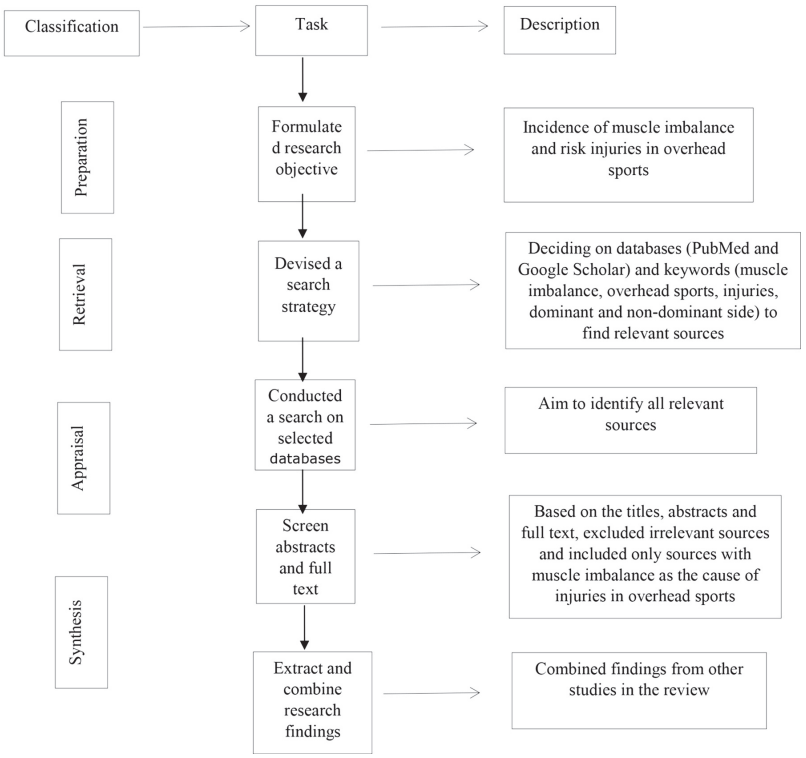

FIGURE 2. Search strategy implemented ih the systematic review of the study

Selection Criteria

All studies were first searched for on the internet using Google Scholar and different databases, including PubMed, PsycInfo, Web of Science, ResearchGate, and ScienceDirect. After that, the study screened the literature on the title and abstract using the following criteria; the target population (male and female overhead sport athletes, with overuse injury or pain of the shoulder, elbow, wrist, and lower back), design of the study (inclusive of all designs such as cross-sectional, systematic review, and case-control studies), and study outcomes (prevalence of injuries among overhead athletes associated with the incidence of muscle imbalance).

Results

The search strategy implemented in the review yielded 307 studies, and after deduplication, 157 studies were screened. The study tested 157 abstracts and excluded 120, leaving 43 of the sources for eligibility assessment. Only 11 out of the 43 assessed sources were selected for the systematic review (Figure 1). From Table 1 below, the eleven studies reported muscle imbalance as a key factor in overhead sports injuries.

Table 1. Occurrence of Muscle Imbalance in Overhead Sports

Source	Injury occurs or may occur	Overhead Sport game	Subjects	Imbalance	Recommends
Atan et al., 2019	Shoulder injury	Badminton	14 healthy badminton players (13.07±2.01 years), (153.64±9.18 cm), (44.71±7.28 kg) who played badminton for at least five years.	The players' dominant biceps muscle volumes were greater than the muscle volumes that they did not control. The grip power of their dominant hands even surpassed the other hand.	To focus on specific training to strengthen their bodies' non-dominant hand to avoid muscle imbalance and injury occurrence
Zuzgina & Wdowski, 2019	Injury or shoulder pathology.	Volleyball	19 university level volleyball players (9 men, (81.3±8.0 kg), (21±1 years)]; 10 women, (66.0±8.2 kg), (19±1 years)).	Both men and women displayed asymmetric external/internal relationships with higher non-dominant ratios.	To achieve a balance between rotors outside and inside.
Olivier & Daussin, 2019	An asymmetry in terms of force, shoulder tendon pain.	Water polo	28 female players, (10 non-competitive players and 18 competitive players (19-25 years)	The dominant shoulder is heavier than the non-dominant shoulder.	To improve external rotation (ER) with analytical gestures. Since the water did not provide solid help to regulate the wave, a specific training out of water should be included.

(continued on next page)

(continued from previous page)

Source	Injury occurs or may occur	Overhead Sport game	Subjects	Imbalance	Recommends
Oleksy, Czarny, Bajorek, Król, & Mika, 2018	Shoulder injury.	Volleyball	18 male volleyball players (21-26 years), (186.6±8.4 cm), (85.7±9.8 kg).	Muscle weakness of the shoulder in dominant and non-dominant.	No recommendation given.
Pennock et al., 2018	Oedema or proximal widening of humeral physis, labral tear, partial rotator thickness tear, acromioclavicular joint abnormality, subacromial bursitis, and significant tuberosity cystic alteration.	Baseball	23 baseball players (10-12 years).	Compared to the non-dominant arm, the dominant arm is 8.5 times more likely to have MRI abnormalities.	To use and implement the Early Sports Guidelines.
Correia et al., 2016	LBP.	Tennis	35 players contributed to the report. (28 males, 7 females, ages 18.54 ± 3.00 years).	Asymptomatic participants had greater endurance periods for the flexor and the right side bridge. Lower extensor muscle activation, less rates of co-contraction and less abdominal endurance.	Tennis coaches and clinicians should pay attention to the abdominal capacity of their athletes and evaluate the ability of lumbar stability exercises to stimulate specific trunk muscles.
Sung et al., 2016	Core and non-dominant arm muscle. The damage to the trunk, usually caused by poor posture and improper swinging or by reduced strength of the trunk muscle.	Golf	60 elite golfers (23 to 25 years).	The dominant arm has a muscle strength of about 10% higher than the non-dominant arm.	To enhance the exercises of both central and non-dominant arm will provide the elite or professional golfers with an appropriate, tailored training programme.
Couppe et al., 2014	Excessive or minimal ROM in the shoulder may lead to shoulder diseases such as instability and impingement.	Badminton	31 adolescents; 12 females, (16.8 + 1.6 years), and 19 males (17.1 + 1.6 years).	Internal and external motion ranges were smaller on the dominant side compared to the non-dominant side on both group's players.	Preventive strength training with proper restitution to stabilize and support the rotator cuff could be even more necessary in females than males to minimize the risk of shoulder injury.
Noguchi et al., 2014	In baseball players, joint upper limb injuries such as baseball elbow (medial epicondylitis) and rotator cuff tears are normal due to overuse and throwing with poor technique.	Baseball	33 Fit, Right-handed, university players (20.4 + 1.1 years) with an average baseball experience.	Correlations between the muscle strength for handgrip and elbow flexion of both the upper limbs were important and moderately strong at all loads.	A training programme to overcome the gaps in skill. For example, light load dumbbell or tube training may be used to improve the strength of the weaker side subscapular muscles and help prevent joint damage.
Tonin, Stražar, Burger, & Vidmar, 2013	Shoulders injury (changes in rotational strength, symptoms of SICK scapula syndrome, and glenohumeral (GH) joint capsule muscle instability contracture).	Volleyball and Handball	36 female players were split into two groups: the symptomatic group included 14 athletes (positive shoulder injury history and detailed shoulder tests) and the asymptomatic group included 22 athletes (negative shoulder injury history and other testing of the shoulder).	Reduced internal rotation and increased external rotation, lower spiking and traditional ratios, lower eccentric external rotor peak torques, and slightly lower eccentric internal rotor peak torques on the dominant side relative to the non-dominant side.	Adjusted clinical and isokinetic shoulder exercise.

Discussion

Findings indicated a significant correlation between muscle imbalance and damages such as lower back, shoulder, wrist, and elbow injury among overhead athletes. Muscle imbalance exposes athletes to an increased risk of joint disorders (Noguchi et al., 2014). Moreover, players of overhead sports are likely to suffer injuries attributed to muscle imbalance because of the different muscle forces applied in the dominant and non-dominant arms (Sung, Park, Kim, Kwon, & Lim, 2016). Scholars maintain that the dominant arm applies muscle force nearly 10% greater than the non-dominant arm (Betchol, 1954; Gedela et al., 2008). The dominant shoulder of most players tends to be stronger than their non-dominant shoulder. This imbalance increases the risk of injury to the shoulder region of an athlete participating in an overhead sport such as water polo (Olivier & Daussin, 2019). Another study identified an imbalance among golf athletes in the dextral arm muscles and sinistral arm muscles (Sung et al., 2016). Athletes who are unskilled in using the sinistral muscles depend on dextral muscles and are required to strengthen the dominant upper limb to maintain a balance between their arms (Sung et al., 2016).

Results of the review illustrated that muscle imbalance is attributable to weaknesses in different regions of the upper limb, including the lower and middle trapezius, infraspinatus, deltoid, serratus anterior, and when coupled with the tightness of levator scapula, upper trapezius, and pectorals which increases the risk of structural damage for the athletes (Page et al., 2011). The study also found the asymmetric nature of movements of an athlete's shoulder as a crucial cause of strength imbalances. Overhead sports, such as swimming and baseball, were found to expose athletes to functional impingement as a result of instability and muscle imbalance.

Additionally, the systematic review found that the external and internal rotators play a crucial role in stabilizing the glenohumeral joint, and a failure in achieving a balance results in injuries among overhead athletes. Muscle imbalance in the dominant and non-dominant sides of volleyball athletes exposed them to shoulder injuries. The results of the review added to existing research findings that confirm the association between muscle imbalance and overhead sports injuries. Wang, Macfarlane and Cochrane (2000) also related muscle imbalance to isokinetic muscle strength; musculoskeletal discomfort, pain, and weaknesses in the shoulder regions are attributed to concentric and eccentric contractions on the dominant and non-dominant shoulders of athletes.

Another study found that muscle imbalance associated with differences in the dominant and non-dominant arms to have a significant effect on baseball players. The study reported that the dominant arm was likely to have an abnormality on MRI that was 8.5 times more than the non-dominant arm, most of the baseball athletes are at risk of being diagnosed with rotator cuff injury, internal impingement lesions, and labral tears (Pennock et al., 2018).

In another study, the researchers discovered differences in trunk fatigue and the activation profile among tennis athletes, the players suffering from LBP were found to have minimal endurance time for their abdominal muscles. Furthermore, the extensor muscle activation procedure was also distinct among the players. The study reveals the importance of addressing problems with abdominal muscles and the activation of distinct trunk muscles, especially in lumbar stability activities, to help minimize the impact of muscle imbalance (Correia et al., 2016).

Noormohammadpour et al. (2016) also examine the prevalence of LBP in distinct overhead sports among female athletes. Research results involving 1,059 overhead athletes with a median age of 23.1 years indicate a 39.0% prevalence of LBP with badminton (42.4%), basketball (47.9%), and karate (44.0%). Lumbar kinematics tests during tennis serves also showed higher lateral flexion moments in LBP matches, which could be a possible injury mechanism (Fett, Trompeter & Platen, 2019).

Oleksy et al. (2018) discovered that differences in contralateral muscle fatigability might result in muscle imbalance and hence expose athletes to acute injury. However, a lack of differences in shoulder muscles of the dominant and non-dominant sides may not be a significant cause of pathological changes among volleyball players. The study concluded that asymmetric shoulder loading for volleyball athletes should not be assumed to be a potential risk factor for injuries to the shoulder region.

In another study that sought to evaluate the difference in dominant and non-dominant functioning of non-athletes and athletes' arms, it was found that the dominant shoulder of handball and volleyball players had more scapular downward and upward rotation, especially in scapular rest (Hosseinimehr, Anbarian, Norasteh, Fardmal, & Khosravi, 2015). In contrast, the study found no significant asymmetry in the dominant and non-dominant shoulders of non-athletes in distinct abduction angles when performing a scapulohumeral rhythm or upward scapular rotation. Also, from the review, the study found that muscle imbalance resulted from side-related adaptations of musculoskeletal and the different techniques used in frequency and pattern of the dominant and non-dominant arm.

Tonin et al. (2013) examined rotational mobility transitions associated with muscle imbalances from which the study identifies repetitive overhead movements, such as a decrease in the dominant external rotation, a higher deficit of the dominant eccentric external rotation peak torques, and a higher dominant rotator fatigue association with previous pain injury in the shoulders. Specific physiological shifts are interrelated (rotational mobility, symptoms of SICK scapula, and glenohumeral muscular imbalances). As a means of prevention and recovery for the at-risk athletes.

The study also revealed some of the crucial muscles that help overhead athletes avoid potential injuries, including the use of core muscles, rotator cuff muscle in strength training to enhance the strength of external rotation muscle (Couppe et al., 2014). The dextral arm muscles and sinistral arm muscles, and core muscles are essential for the golf and badminton players since they stabilize the backbone and maintain a player's pelvis balance in swinging motion (Sung et al., 2016). Scholars have also identified other muscles crucial for athletes, such as the trapezius muscles and serratus anterior, which are important in maintaining a balance during upward rotation. Moreover, Lantz and McNamara (2003) identified additional muscles crucial among overhead sports players, including the middle trapezius, rhomboids, and lower trapezius muscles, which help maintain the stability of scapula that may result in shoulder injury attributed to muscle imbalance.

The importance of muscle fatigue as a risk factor for shoulder injury in overhead athletes was highlighted by Andrade et al. (2016). A higher incidence of late-game injury than ear-

ly-game injury was documented and indicated that this fatigue might affect muscle strength balance and thus shoulder joint stabilization.

Conclusion

The overall findings of this study showed that overhead athletes are susceptible to shoulder, elbow, lower back, and wrist injuries attributed to muscle imbalances in either the dominant or non-dominant side. Athletes should engage in training and therapeutic programmes that help them learn techniques of avoiding potential injuries. Preventive strength training can help players balance and stabilize the rotator cuff muscle and minimize the chances of injuries. Furthermore, training allows players to learn proper throwing and pitching techniques, as well as restoring neuromuscular function to minimize the impact of muscle imbalance. Findings from the systematic review indicated that limited studies focus on the non-dominant side; thus, further research should focus on muscle imbalance in non-dominant upper limbs and its connection to overhead sport injuries and provide important programmes and exercise that can stabilize muscles in the non-dominant side.

Acknowledgements
There are no acknowledgements.

Conflict of Interest
The authors declare that there are no conflicts of interest.

Received: 26 November 2020 | **Accepted:** 17 January 2021 | **Published:** 01 October 2021

References

Andrade, M.D.S., Fleury, A.M., de Lira, C.A.B., Dubas, J.P., & da Silva, A.C. (2010). Profile of isokinetic eccentric-to-concentric strength ratios of shoulder rotator muscles in elite female team handball players. *Journal of Sports Sciences*, *28*(7), 743-749.

Andrade, M.S., de Carvalho Koffes, F., Benedito-Silva, A.A., da Silva, A.C., & de Lira, C.A.B. (2016). Effect of fatigue caused by a simulated handball game on ball throwing velocity, shoulder muscle strength and balance ratio: a prospective study. *BMC Sports Science, Medicine and Rehabilitation*, *8*(1), 13.

Atan, T, Yüceloğlu Keskin, D, Çamlidağ, İ, & Derebaşi, D. (2019). Analysis of dominant and non-dominant biceps and deltoid muscle volumes of badminton players. *Turkish Journal of Sport and Exercise*, *21*(2), 323-327. doi: 10.15314/tsed.496133

Bahr, R., Andersen, S. O., Løken, S., Fossan, B., Hansen, T., & Holme, I. (2004). Low back pain among endurance athletes with and without specific back loading—a cross-sectional survey of cross country skiers, rowers, orienteers, and nonathletic controls. *Spine*, *29*(4), 449-454.

Baranto, A., Hellström, M., Cederlund, C.G., Nyman, R., & Swärd, L. (2009). Back pain and MRI changes in the thoraco-lumbar spine of top athletes in four different sports: a 15 year follow-up study. *Knee Surgery, Sports Traumatology, Arthroscopy*, *17*(9), 1125 1134.

Betchol, C.O. (1954). Grip test: the use of a dynamometer with adjustable handle spacing. *J Bone Jt Surg AM*, *36*, 820-4.

Borsa, P.A., Laudner, K.G., & Sauers, E.L. (2008). Mobility and stability adaptations in the shoulder of the overhead athlete. *Sports Medicine*, *38*(1), 17-36.

Burkhart, S.S., Morgan, C.D., & Kibler, W.B. (2003). The disabled throwing shoulder: spectrum of pathology Part III: The SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthroscopy*, *19*(6), 641-661.

Challoumas, D., Artemiou, A., & Dimitrakakis, G. (2017). Dominant vs. non-dominant shoulder morphology in volleyball players and associations with shoulder pain and spike speed. *Journal of Sports Sciences*, *35*(1), 65-73.

Codine, P., Bernard, P.L., Pocholle, M., Benaim, C., & Brun, V. (1997). Influence of sports discipline on shoulder rotator cuff balance. *Medicine & Science in Sports & Exercise*, *29*(11), 1400-1405.

Correia, J.P., Oliveira, R., Vaz, J.R., Silva, L., & Pezarat-Correia, P. (2016). Trunk muscle activation, fatigue and low back pain in tennis players. *Journal of Science and Medicine in Sport*, *19*(4), 311-316.

Couppe, C., Thorborg, K., Hansen, M., Fahlström, M., Bjordal, J.M., Nielsen, D., & Magnusson, SP. (2014). Shoulder rotational profiles in young healthy elite female and male badminton players. *Scandinavian Journal of Medicine & Science in Sports*, *24*(1), 122-128.

Edmonds, E.W., & Dengerink, D.D. (2014). Common conditions in the overhead athlete. *American Family Physician*, *89*(7), 537-541.

Edouard, P., Damotte, A., Lance, G., Degache, F., & Calmels, P. (2013). Static and dynamic shoulder stabilizer adaptations in javelin throwers: a preliminary study. *Isokinetics and Exercise Science*, *21*(1), 47-55.

Escamilla, R.F., Fleisig, G.S., Barrentine, S.W., Zheng, N., & Andrews, J.R. (1998). Kinematic comparisons of throwing different types of baseball pitches. *Journal of Applied Biomechanics*, *14*(1), 1-23.

Fahlström, M., & Söderman, K. (2007). Decreased shoulder function and pain common in recreational badminton players. *Scandinavian Journal of Medicine & Science in Sports*, *17*(3), 246-251.

Fahlström, M., Yeap, J. S., Alfredson, H., & Söderman, K. (2006). Shoulder pain–a common problem in world-class badminton players. *Scandinavian Journal of Medicine & Science in Sports*, *16*(3), 168-173.

Fett, D., Trompeter, K., & Platen, P. (s2019). Prevalence of back pain in a group of elite athletes exposed to repetitive overhead activity. *PloS one*, *14*(1), e0210429. https://doi.org/10.1371/journal.pone.0210429

Fleisig, G.S., Escamilla, R.F., Andrews, J.R., Matsuo, T., Satterwhite, Y., & Barrentine, S.W. (1996). Kinematic and kinetic comparison between baseball pitching and football passing. *Journal of Applied Biomechanics*, *12*(2), 207-224.

Gedela, R.K., Kirby, A., & Huhtala, H. (2008). Does the dominant hand possess 10% greater grip strength than the non-dominant hand. *Indian Journal of Physiotherapy*, *45*(2), 116 121.

Gil, J.A., & Kakar, S. (2019). Hand and wrist injuries in tennis players. *Current Reviews in Musculoskeletal Medicine*, *12*(2), 87-97.

Hootman, J.M., Dick, R., & Agel, J. (2007). Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *Journal of Athletic Training*, *42*(2), 311.

Hosseinimehr, S.H., Anbarian, M., Norasteh, A.A., Fardmal, J., & Khosravi, M.T. (2015). The comparison of scapular upward rotation and scapulohumeral rhythm between dominant and non-dominant shoulder in male overhead athletes and non-athletes. *Manual Therapy*, *20*(6), 758-762.

Kaplan, D.Ö. (2016). Evaluating the relation between dominant and non-dominant hand perimeters and handgrip strength of basketball, volleyball, badminton and handball athletes. *International Journal of Environmental and Science Education*, *11*(10), 3297 3309.

Kibler, W.B. (1998). The role of the scapula in athletic shoulder function. *The American Journal of Sports Medicine*, *26*(2), 325-337.

Koh, J., & Dietz, J. (2005). Osteoarthritis in other joints (hip, elbow, foot, ankle, toes, wrist) after sports injuries. *Clinics in Sports Medicine*, *24*(1), 57-70.

Kraan, R.B., de Nobel, D., Eygendaal, D., Daams, J.G., Kuijer, P.P.F., & Maas, M. (2019). Incidence, prevalence, and risk factors for elbow and shoulder overuse injuries in youth athletes: A systematic review. *Translational Sports Medicine*, *2*(4), 186-195.

Lam, K.Y., & Siow, H.M. (2012). Conservative treatment for juvenile osteochondritis dissecans of the talus. *Journal of Orthopaedic Surgery*, *20*(2), 176-180.

Lantz, J., & McNamara, S. (2003). Modifying the latissimus pull-down exercise for athletes with shoulder injury. *Strength & Conditioning Journal*, *25*(6), 67-69.

Laudner, K., & Sipes, R. (2009). The incidence of shoulder injury among collegiate overhead athletes. *Journal of Intercollegiate Sport*, *2*(2), 260-268.

Lee, K.S., Tuite, M.J., & Rosas, H.G. (2010). Elbow Injuries. In *Essential Radiology for Sports Medicine* (127-141). Springer, New York, NY.

Lin, J.J., Wu, Y.T., Wang, S.F., & Chen, S.Y. (2005). Trapezius muscle imbalance in individuals suffering from frozen shoulder syndrome. *Clinical Rheumatology*, *24*(6), 569 575.

Lupo, C., Capranica, L., Cugliari, G., Gomez, M. A., & Tessitore, A. (2016). Tactical swimming activity and heart rate aspects of youth water polo game. *The Journal of Sports Medicine and Physical Fitness*, *56*(9), 997-1006.

Murray, I.R., Goudie, E.B., Petrigliano, F.A., & Robinson, C.M. (2013). Functional anatomy and biomechanics of shoulder stability in the athlete. *Clinics in Sports Medicine*, *32*(4), 607 624.

Nekooei, P., Tengku-Fadilah, T.K., Amri, S., Baki, R.B., Majlesi, S., & Nekouei, P. (2019). Anatomical shoulder movement strength imbalance among water polo overhead athletes. *International Journal of Kinesiology and Sports Science*, *7*(2), 15-20.

Noguchi, T., Demura, S., Takahashi, K., Demura, G., & Mori, Y. (2014). Differences in muscle power between the dominant and non-dominant

upper limbs of baseball players. *The Journal of Strength & Conditioning Research*, *28*(1), 82-86.

Noormohammadpour, P., Rostami, M., Mansournia, M.A., Farahbakhsh, F., Shahi, M.H.P., & Kordi, R. (2016). Low back pain status of female university students in relation to different sport activities. *European Spine Journal*, *25*(4), 1196-1203.

Oleksy, L., Czarny, W., Bajorek, W., Król, P., & Mika, A. (2018). The evaluation of shoulder muscle fatigue in volleyball players. *Journal of Novel Physiotherapies*, *8*(388), 2.

Olivier, N., & Daussin, F. (2019). Isokinetic torque imbalances of shoulder of the French women's national water polo team. *Science & Sports*, *34*(2), 82-87.

Page, P. (2011). Shoulder muscle imbalance and subacromial impingement syndrome in overhead athletes. *International Journal of Sports Physical Therapy*, *6*(1), 51.

Page, P., Frank, C., & Lardner, R. (2011). Assessment and treatment of muscle imbalance: the Janda approach. *J Orthop Sports Phys Ther*, *41*(10), 799-800.

Parikh, H., Case, A.L., Hogarth, D.A., & Abzug, J. M. (2020). Pediatric Sports Injuries: Little League Elbow, Osteochondritis Dissecans of the Elbow, Gymnast Wrist. In *Pediatric Hand Therapy* (pp. 331-357). Elsevier.

Pennock, A.T., Dwek, J., Levy, E., Stearns, P., Manning, J., Dennis, M.M., & Taylor, K.S. (2018). Shoulder MRI abnormalities in asymptomatic little league baseball players. *Orthopaedic Journal of Sports Medicine*, *6*(2), 2325967118756825.

Putty, B.B. (2010). Upper limb injuries in sports. *British Journal of Sports Medicine*, *44*(Suppl 1), i3.

Roos, K.G., Marshall, S.W., Kerr, Z.Y., Golightly, Y.M., Kucera, K.L., Myers, J.B., ... & Comstock, R. D. (2015). Epidemiology of overuse injuries in collegiate and high school athletics in the United States. *The American Journal of Sports Medicine*, *43*(7), 1790 1797.

Sirota, S.C., Malanga, G.A., Eischen, J.J., & Laskowski, E.R. (1997). An eccentric- and concentric strength profile of shoulder external and internal rotator muscles in professional baseball pitchers. *The American Journal of Sports Medicine*, *25*(1), 59-64.

Sung, D.J., Park, S.J., Kim, S., Kwon, M.S., & Lim, Y.T. (2016). Effects of core and non- dominant arm strength training on drive distance in elite golfers. *Journal of Sport and Health Science*, *5*(2), 219-225.

Tonin, K., Stražar, K., Burger, H., & Vidmar, G. (2013). Adaptive changes in the dominant shoulders of female professional overhead athletes: mutual association and relation to shoulder injury. *International Journal of Rehabilitation Research*, *36*(3), 228-235

Trompeter, K., Fett, D., & Platen, P. (2017). Prevalence of back pain in sports: a systematic review of the literature. *Sports Medicine*, *47*(6), 1183-1207.

Tunås, P., Nilstad, A., & Myklebust, G. (2015). Low back pain in female elite football and handball players compared with an active control group. *Knee Surgery, Sports Traumatology, Arthroscopy*, *23*(9), 2540-2547.

Wang, H.K., Macfarlane, A., & Cochrane, T. (2000). Isokinetic performance and shoulder mobility in elite volleyball athletes from the United Kingdom. *British Journal of Sports Medicine*, *34*(1), 39-43.

Wilk, K.E., Ellenbecker, T.S., & Macrina, L.C. (2015). Rehabilitation of the overhead athlete's elbow. In *Elbow Ulnar Collateral Ligament Injury* (pp. 227-259). Springer, Boston, MA.

Wilk, K.E., Obma, P., Simpson, C.D., Cain, E.L., Dugas, J., & Andrews, J.R. (2009). Shoulder injuries in the overhead athlete. *Journal of Orthopaedic & Sports Physical Therapy*, *39*(2), 38-54.

Wright, A.A., Hegedus, E.J., Tarara, D.T., Ray, S.C., & Dischiavi, S.L. (2018). Exercise prescription for overhead athletes with shoulder pathology: a systematic review with best evidence synthesis. *British Journal Sports Medicine*, *52*(4), 231-237.

Zellner, B., & May, M.M. (2013). Elbow injuries in the young athlete—an orthopedic perspective. *Pediatric Radiology*, *43*(1), 129-134.

Zuzgina, O., & Wdowski, M.M. (2019). Asymmetry of dominant and non-dominant shoulders in university level men and women volleyball players. *Human Movement*, *20*(2), 19-27.