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Acute effects of static-stretching on the shoulder joint-position sense: A randomized controlled crossover trial

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ABSTRACT

Introduction: The influence of static-stretching on variables like shoulder muscle strength has been addressed in different sports. However, its effect on the joint-position sense is poorly investigated.
Objectives: This study aimed to investigate the acute effects of different durations of static-stretching on the shoulder-joint position sense of overhead athletes.
Methodology: A three-period block-randomized controlled crossover trial was conducted from December 2023 to February 2024 at a rehabilitation and health research laboratory with 17 competitive overhead athletes (9 males and 8 females), aged 18-30 years, with normal range of motion of shoulder flexion. Excluded were those with history of shoulder injury in the last 6 months, and with positive shoulder integrity tests. In random order, all participants performed 3 conditions: control (5-minute rest), and a 30- or 90-seconds static-stretching of muscles around the shoulder. Before and immediately after these conditions, position sense was tested through active repositioning to 110º of flexion, with a video camera, and described as absolute, relative and variable angular errors. Trial Registration: ClinicalTrials.gov ID - NCT06226974.
Results: A significant increase was only found in the absolute angular errors of the static-stretching of 30 seconds condition between the initial assessment and after the static-stretching ($p=0.015$). However, no differences between conditions were found ($p=0.874$).
Conclusion: Results suggest that static-stretching may have acute effects on the shoulder joint-position sense of overhead athletes depending on its duration, appearing to be harmful when performed for 30 seconds, but innocuous when performed for 90 seconds. Longer durations of static-stretching appear to be safe in the context of overhead sports.

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INFORMAÇÃO DO ARTIGO

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RESUMO

Introdução: A influência do alongamento estático em variáveis como a força muscular do ombro tem sido abordada em diferentes modalidades desportivas. No entanto, o seu efeito na sensação de posição articular é pouco investigado.
Objetivos: Este estudo teve como objetivo investigar os efeitos agudos de diferentes durações de alongamento estático na sensação de posição da articulação do ombro em atletas *overhead*.
Metodologia: Foi conduzido um estudo randomizado controlado em *crossover* de 3 períodos entre dezembro de 2023 e fevereiro de 2024 num laboratório de reabilitação e investigação em saúde com 17 atletas *overhead* de competição (9 homens e 8 mulheres), com idades entre os 18 e os 30 anos, e com amplitude de movimento normal de flexão do ombro. Foram excluídos aqueles com história de lesão do ombro nos últimos 6 meses e com testes de integridade do ombro positivos. Em ordem aleatória, todos os participantes realizaram 3 condições: controlo (descanso de 5 minutos) e alongamento estático dos músculos à volta do ombro durante 30 ou 90 segundos. Antes e imediatamente após estas condições, a sensação de posição foi testada através de reposicionamento ativo para 110º de flexão, com uma câmara de vídeo, e descrita através de erros angulares absolutos, relativos e variáveis. Registo do protocolo: ClinicalTrials.gov ID - NCT06226974.
Resultados: Foi encontrado um aumento significativo apenas nos erros angulares absolutos da condição de alongamento estático de 30 segundos entre a avaliação inicial e após o alongamento estático ($p=0.015$). Contudo, não foram encontradas diferenças entre as condições ($p=0.874$).
Conclusão: Os resultados sugerem que o alongamento estático pode ter efeitos agudos na sensação de posição articular do ombro em atletas *overhead*, dependendo da sua duração, parecendo ser prejudicial quando realizado durante 30 segundos, mas inócuo quando realizado durante 90 segundos. Durações mais longas de alongamento estático parecem ser seguras no contexto de desportos *overhead*.

Introduction

Overhead athletes present a high risk of shoulder injury, especially in gestures involving throwing and hitting.[1] Effectively, as one of the most mobile joints, the shoulder is exposed to wide ranges of motion,[2] making it more susceptible to injuries as consequence of instability.[3] This requires the shoulder to rely on the adequate function of static (capsuloligamentous elements) and dynamic structures (rotator cuff muscles and others).[4] Mechanoreceptors responsible for proprioception information are present in these structures and translate mechanical deformation into neural signals to the central nervous system.[4] According to Ager, Borms, Deschepper, Dhooghe, Dijkhuis, Roy and Cools[2], besides pain, shoulder injuries can lead to altered proprioceptive acuity.

In different sports, warm-ups often involve stretching, as an increased flexibility has been linked to higher ranges of motion and reduced muscle injuries.[5] Particularly static stretching (SS), describes a muscle lengthening for a certain period until reaching a stretch sensation or point of discomfort.[5]

The influence of SS on shoulder muscle strength, has been previously studied, being described that when performed for total periods greater than 60 seconds tend to decrease muscle strength,[6] while durations shorter than this do not seem to influence strength.[7] However, its effect on the shoulder joint position sense (JPS), described as the capacity of memorizing and reproduce one joint position,[8] has not yet been explored.

Effectively, only the study of Björklund, Djupsjöbacka and Crenshaw[9] assessed the effects of the contract-relax method of agonist and antagonist muscles on the shoulder JPS. Despite of the changes that stretching may induce in the muscle spindle, considered the mechanoreceptor with major contribution to proprioception,[10] the authors found no acute effects of this type of stretching on the shoulder position sense.

Besides muscle strength, to date, there are no investigations able to answer if SS is safe to apply without harming the shoulder JPS, and that even test different durations of SS, which highlights the need for studies addressing this topic. In that sense, this study aimed to investigate the acute effects of different durations of SS on the shoulder JPS of overhead athletes. We hypothesize that, similar to muscle strength, longer durations of SS may impair the shoulder JPS.

Methodology

Participants and design

This trial followed a three-block randomized controlled crossover design, with 3 months of duration (from December 2023 to January 2024), and was described according to the CONSORT 2010 statement (extension to randomized crossover trials).[11] Trial registration number is ClinicalTrials.gov ID - NCT06226974.

A convenience sample of 17 overhead athletes (9 males; 8 females), were assessed at the rehabilitation and health research laboratory of the university. Subjects were included if they were aged 18-30 years, and competitive overhead athletes (e.g. handball, basketball, volleyball or swimming), with normal flexion range of motion of the shoulder. Excluded were those with history of shoulder injury in the last 6 months, and with positive shoulder integrity tests (anterior drawer; fulcrum test; Jerk test; and sulcus sign). Participants were also asked to avoid coffee and alcohol in the previous 24 hours to the assessments. A block randomization was conducted in an online platform, in order to guarantee an equal sample size across the study conditions.

A sample characterization questionnaire was filled to assess variables such as sex, age, sport practiced, years of practice, weight, height, body mass index and dominant side. The dominant upper limb was determined as the preferred limb to throw a ball.[12] In all participants, the dominant side was the right.

All participants performed the 3 study conditions in random order and with 1 week of interval between them: two experimental conditions of SS of 30 seconds[13] and 90 seconds[14] of muscles around the shoulder; and one control condition, of a 5-minute rest period.

The Ethical Committee of Fernando Pessoa University approved the study with the code ESS/FSA – 374/23-3. To participate in the study, all volunteers signed an informed consent, and all the assumptions from the Declaration of Helsinki were ensured.

Static stretching protocol

SS protocol followed the instructions of Busch, Browstein and Ulm[15]:

- Shoulder extension with the hand resting on a door;
- Doorway stretch, maintaining shoulder horizontal abduction and 90º of elbow flexion against a door;
- Shoulder flexion, with the arms above the head and against a wall;
- Cross-body stretch describing a maximal horizontal adduction and the opposite hand holding the position;
- Overhead triceps, with the arm above the head and that elbow flexed, while the other hand pulls the elbow;
- Internal Rotation 90° stretch – with the shoulder and elbow at 90º of flexion, the opposite hand and forearm forces the internal rotation.
- Every stretch was conducted in the dominant upper limb for 30 or 90 seconds, according to the condition under study.

Assessment of shoulder joint position sense

Shoulder JPS was assessed in the dominant upper limb with the athletes in the standing position, both before and immediately after the 3 conditions, to 110º of flexion,[16] defined by a goniometer. The upper limb was passively moved by the investigator from the initial position (0º) to the test range (110º) (passive positioning), and the participant was then asked to actively maintain the position for 5 seconds and memorize it. After that, they had to come back the arm to the initial position, and immediately after, to reposition it actively, trying to reproduce the previous arm position, also maintaining the position for 5 seconds. The participants performed 3 repositioning attempts, and were blindfolded during the entire assessment.

The procedure was filmed using a video camera, saving a distance that guaranteed that the involved segments were within the field of view. Markers were fixed to the skin in the 3 locations: the acromion, the lateral humerus epicondyle and the femur greater trochanter. Angles analysis was subsequently performed in the Kinovea 0.8.15 software, considered a reliable tool to assess shoulder joint motion,[17] in which the last 3 seconds of each positioning and repositioning were considered. The average of the 3 attempts was calculated and the repositioning errors were then expressed as:

- the absolute angular error, consisting of the absolute difference between the target range and the achieved range;[18]
- the relative angular error, defined as the arithmetic difference between the target range and the achieved range, reporting directional bias, where negative values indicate an overestimation of the target range, while positive values indicate an underestimation;[18]
- the variable angular error, defined as the standard deviation of the 3 attempts, representing the consistency between repositionings.[19]

Statistical analysis

Data analysis was conducted with the software IBM SPSS v.26. A new variable was calculated considering the difference (Dif) in the absolute, relative or variable errors between the assessment after and before the control or SS interventions (assessment after - assessment before). The Shapiro-Wilk test was conducted to assess the normality of the distribution of variables, which was not verified.

Variables were then expressed as Median and Interquartile Range (Med; IQR). Non-parametric tests were conducted: the Wilcoxon test for intragroup comparison of changes in absolute, relative, and variable angular errors between before and after the SS or control interventions; and the Friedman's test for intergroup comparison to test the existence of differences between conditions in the assessments before and after the SS interventions or control. For all analyses, a significance level of 5% was considered.

Results

All 17 participants successfully completed the 3 conditions of the study (Figure 1). Characterization of the sample is presented in table 1, regarding age, weight, height, BMI and years of sport practice.

Figure 1. CONSORT flow diagram for crossover trials.

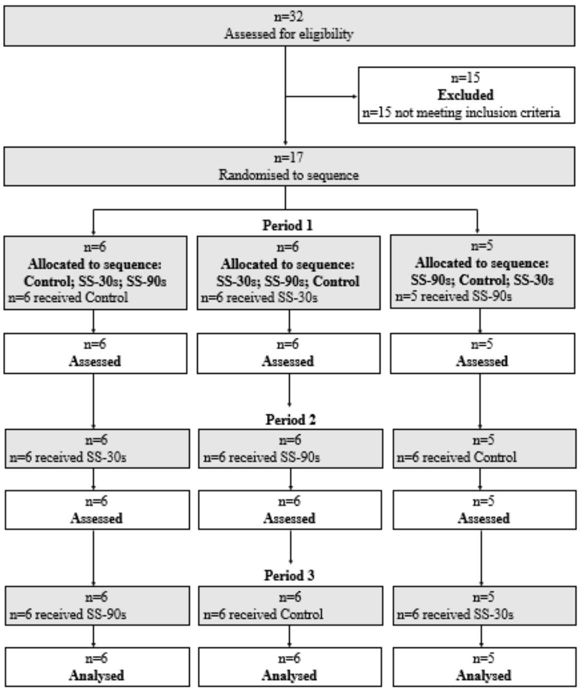

Table 1. Sample characterization.

Variable	Med; IQR
Age (years)	22; 2
Weight (kg)	70; 17
Height (m)	1.70; 0.07
BMI (kg/m^2)	24.2; 3.9
Years of sport practice (years)	10; 9

Med – median; IQR – interquartile range

Tables 2, 3 and 4 describe the intra- and intergroup comparisons regarding the absolute, relative and variable angular errors, respectively. Significant changes were only found in the absolute angular errors, with the SS-30s condition registering a significant increase in the error between the initial assessment and after the SS (p=0.015). However, no differences between conditions were found in the assessment after (p=0.874). Regarding the relative angular errors, no significant changes were verified (p>0.05). A tendency towards overestimation of the test range was verified, represented by the negative values presented. Finally, the consistency between the 3 repositionings also did not change between the initial assessment and after the SS interventions or control, as the variable angular errors did not change significantly (p>0.05).

Table 2. Intra- and intergroup comparisons in the absolute angular errors.

Condition	Before	After	*p*	*Dif*
	Med; IQR	Med; IQR		Med; IQR
Control	3.1; 3.6	3.2; 4.4	0.868	0.7; 3.8
SS-30s	1.5; 2.1	3.9; 2.8	0.015*	2.2; 3.4
SS-90s	3.8; 3.3	3.6; 5.8	0.925	-0.9; 6.2
p	0.308	0.874		0.197

*Med – median; IQR – interquartile range; SS – static stretching; Diff – difference between the assessments after and before conditions; *p<0.05*

Table 3. Intra- and intergroup comparisons in the relative angular errors.

Condition	Before	After	*p*	*Dif*
	Med; IQR	Med; IQR		Med; IQR
Control	-0.6; 5.7	-0.7; 4.8	0.569	1.3; 6.4
SS-30s	-0.1; 2.8	-0.7; 7.8	0.379	-2.2; 6.1
SS-90s	-2.3; 8.4	-0.7; 7.7	0.570	1.7; 7.8
p	0.901	0.753		0.291

*Med – median; IQR – interquartile range; SS – static stretching; Diff – difference between the assessments after and before conditions; *p<0.05*

Table 4. Intra- and intergroup comparisons in the variable angular errors.

Condition	Before	After	*p*	*Dif*
	Med; IQR	Med; IQR		Med; AIQ
Control	2.6; 2.0	1.4; 1.0	0.056	-0.5: 2.2
SS-30s	1.9; 0.8	1.5; 1.0	0.055	-0.9; 1.6
SS-90s	1.9; 1.8	1.9; 1.8	0.962	-0.1; 1.6
p	1.000	0.080		0.662

*Med – median; IQR – interquartile range; SS – static stretching; Diff – difference between the assessments after and before conditions; *p<0.05*

Discussion

This study aimed to investigate the acute effects of SS on the shoulder JPS of overhead athletes.

According to Proske, Morgan and Gregory[20], since the muscle spindle has thixotropic properties, muscle stretching may produce changes on its proprioceptive input. It has also been suggested by Larsen et al.[21] that stretching increases the muscle spindle‘ sensibility, which in theory, would improve the capacity of an individual to sense limb position. However, our results suggest that SS of muscles around the shoulder worsened the JPS, but only when performed for 30 seconds, while no effects were found regarding the duration of 90 seconds.

To date, only the study of Björklund, Djupsjöbacka and Crenshaw[9] investigated the effect of stretching on the shoulder JPS, having reported no acute effects. However, several differences between the studies can be highlighted. First, the study of Björklund, Djupsjöbacka and Crenshaw[9] used a different type of stretching, consisting of a contract-relax stretch method, which by itself may influence differently the muscle mechanoreceptors responsible for the proprioceptive acuity of the shoulder. Second, distinct protocols of JPS assessment were used. Björklund, Djupsjöbacka and Crenshaw[9] used a repositioning to two ranges of horizontal adduction (15º and 30º), while the present study assessed the ability to reproduce one range to flexion (110º). Furthermore, both studies adopted a crossover design. However, in the present study, a fixed interval of 1 week between conditions was saved, while Björklund, Djupsjöbacka and Crenshaw[9] reported an average time between conditions of 7.2 days, and inclusive in some participants only 2 days were saved, which may have introduced variability, and also raises the question whether 2 days of interval in some individuals were enough to mitigate the effects of the previous condition. Despite of the already listed methodological differences, as in the present study, Björklund, Djupsjöbacka and Crenshaw[9] did not find any change after the protocol in the variable angular errors, which reveals that the stretching did not affect the consistency between repositionings.

Despite the lack of studies in the shoulder, several authors have investigated the effect of SS on the JPS of the knee joint. Nevertheless, conflicting results between them can be found. Larsen et al.[21] did not report any effect on the knee JPS after SS of the quadriceps and hamstrings during 3 sets of 30 seconds, with an interval of 30 seconds. On the contrary, Ghaffarinejad, Taghizadeh and Mohammadi[22] used the same SS protocol and found a significant decrease in the repositioning errors after SS of the quadriceps, of the hamstrings and the adductors when the assessment was conducted to the range of 45º, while no significant effects were seen for the range of 20º. These results suggest that SS affected more the muscle mechanoreceptors, which are more active in intermediate ranges such as 45º of knee flexion,[19] than the joint mechanoreceptors, more active in the extremes of the joint ROM (20º).[23] Despite of the differences in the SS protocol, similarly to Ghaffarinejad, Taghizadeh and Mohammadi[22], Walsh[24] also found a significant improvement of the knee JPS after 90 seconds of SS of the quadriceps and hamstrings. In the present study, one of the conditions consisted of a SS of 90 seconds, but no significant changes were found between the assessments before and after the SS, which is not in line with the results of Walsh[24]. This may suggest that the number of muscles stretched may influence differently the proprioceptive acuity of a given joint. It is also important to highlight that the participants of Walsh[24] were healthy physically active adults, but not athletes such as the individuals of our sample. Previous investigations have shown a better repositioning ability in trained individuals, when compared to those non-trained.[25,26] Effectively, it has been described that training induces morphological adaptations in the muscle spindle's intrafusal fibres, reflecting in the latency decrease of the stretch reflex's, and increasing its amplitude.[27] It is possible that since the sample of the present study included only athletes, which accordingly to the previous evidence might present better proprioceptive acuity, the magnitude of effect of the SS may be lower than in individuals who are active but not involved in sports.

Finally, Oskouei, Abazari, Kahjoogh, Goljaryan and Zohrabi[28] reported a negative effect of SS on the knee JPS of soccer players when executed for 3 repetitions of 30 seconds in the hamstrings, but not when performed only in the quadriceps or in both muscle groups. Proprioceptive input from both agonist and antagonist muscles contribute to the sense of limb position. However, it is argued that the input from the muscles being stretched during the repositioning task have the most contribution,[29,30] which can be attributed to the muscle spindles function.[31] Since the authors adopted a repositioning method from flexion to extension, the authors explained that since the hamstring were being stretched during the task, this condition was the only one that affected the knee JPS. In that sense, it is possible that conducting other repositionings in different positions or directions would produce other results.

Some limitations of this study must be recognized. First, a crossover design was selected, since it reduces the variability between participants of the different conditions. However, this design has some disadvantages such as possible larger dropouts and the learning effect. Nevertheless, all participants performed the three conditions of the study, ensuring a 0% dropout rate; a block randomization of the order of conditions was performed; and also, a washout period between conditions of one week was assured, in order to recover from the previous condition. Second, the sample size, being possible that a larger number of participants could have produced more robust results, and effectively a sample size calculation was not performed. Third, only the acute effects of SS were assessed. Fourth, only one test range was tested, corresponding to an intermediate range of the shoulder ROM, where muscle mechanoreceptors are more active.[32] As SS leads to changes in muscle length, the targeted mechanoreceptors are most likely the muscle ones.

Conclusion

The results of this study suggest that SS may have acute effects on the shoulder JPS of overhead athletes depending on its duration, appearing to be harmful when performed for 30 seconds, but innocuous when performed for 90 seconds. Longer durations of SS appear to be safe in the context of overhead sports.

Future research about this topic should be conducted with more robust samples in order to compare with the present results. Regarding the SS of 30 seconds, as it was reported to be harmful to the shoulder JPS, it should also be explored its effects at long-term to see if these continue for longer periods. Finally, as overhead sports frequently involve extreme motions of the shoulder, it is also recommended to assess JPS at extreme ranges of the shoulder ROM, where joint mechanoreceptors can be targeted.[33]

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Conflicts of Interest

Authors state no conflict of interest.

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