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Article

# Rethinking Warm-Up in Overhead Exercise: Acute Shoulder Responses to a Strength- and Mobility-Oriented Protocol in Youth Athletes

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## Abstract

Overhead sports place high demands on the shoulder complex, making warm-up specificity relevant for acute readiness. This randomized controlled pilot trial compared the immediate effects of a shoulder-specific warm-up with a habitual routine in 24 youth competitive overhead athletes (14–20 years), allocated to an experimental group (EG = 12) and a standard warm-up group (SWG = 12). Outcome measures were collected before and immediately after warm-up and included shoulder flexion range of motion (ROM), handgrip strength, Closed Kinetic Chain Upper Extremity Stability (CKCUES) performance, and post-warm-up Rating of Perceived Exertion (RPE; Borg CR-10). A significant group-by-time interaction was found for right shoulder flexion ROM ( $p = 0.003$ ,  $\eta^2p = 0.346$ ), with a significant increase in the EG from baseline to post-test ( $p = 0.008$ ). No significant effects were observed for left shoulder flexion ROM, handgrip strength, or CKCUES performance. Post-warm-up RPE was significantly higher in the EG than in the SWG ( $p = 0.041$ ). These preliminary findings support the practical value of more targeted warm-up strategies in overhead sports, while larger longitudinal studies are needed to confirm their broader functional relevance.

**Keywords:** overhead athletes; youth athletes; shoulder warm-up; upper extremity performance; handgrip strength; CKCUES

## 1. Introduction

In sports characterized by repeated overhead actions (such as water polo, weightlifting, rhythmic gymnastics, and shot put), shoulder efficiency does not depend solely on joint range of motion (ROM), but rather emerges from the coordinated interaction between strength, neuromuscular control, and movement perception [1]. In this contexts, the athlete's ability to stabilize the scapulohumeral joint at ranges of maximal mechanical load represents a fundamental factor for both performance and injury prevention [2]. Although many preparation and prevention protocols

include shoulder mobility and strengthening exercises, these are often relegated to the final phases of the training session, thereby reducing their potential immediate impact on sport-specific performance [3–5]. A more integrated approach, which considers the body as a dynamic and interconnected system, is grounded in the principles of biotensegrity, according to which movement arises from the balance between tensile continuity and compressive discontinuity within a single functional network [6]. This perspective emphasizes that the quality of motor performance is determined not only by the physical properties of body segments but also by how the athlete perceives, anticipates, and organizes movement. Within this framework, strength and mobility should not be viewed as separate capacities but rather as complementary components of a unified motor strategy integrating structure, function, and perception [7]. Today, the contemporary sports landscape is characterized by increasing specialization even among young athletes. This trend highlights the need for scientific research to develop increasingly specific, innovative, and long-term sustainable tools capable of supporting athletes not only in the immediate expression of performance but also in building developmental pathways that minimize injury risk [8]. In this context, the warm-up represents a low-cost intervention, performed daily and capable of exerting a meaningful impact on joint and neuromuscular function [9]. However, the literature to date reports heterogeneous findings regarding its effectiveness, likely due to differences in exercise and innovative tool selection, specificity, and intended training objectives [10]. Accordingly, there is a need to propose a targeted warm-up protocol rather than a generic whole-body activation approach, one that is consistent with the biomechanical demands of overhead sports and integrated from both physical and perceptual perspectives [11]. The rationale underlying our approach is that improving the athlete's ability to remain strong and stable even in complex or less frequently used joint positions may facilitate force expression (defined as the application of force to an external object), expand functional ROM, and contribute to reducing the risk of joint overload [12–14]. From a perceptual standpoint, recognizing the role of subjective sensations, e.g. assessed by tools such as the Rating of Perceived Exertion (RPE) scale, may help to better understand motor adaptation, particularly in young competitive athletes who often possess a refined body awareness of sport-specific gestures [15,16]. In light of these considerations, the present pilot study aimed to compare the effects of an active warm-up based on mobility and strength exercises specific to the scapulohumeral joint with those of a traditional warm-up, evaluating changes in ROM, neuromuscular control, and movement perception in young overhead competitive athletes. The objective is to provide an innovative and integrated perspective aligned with the needs of the modern athlete and to contribute to the evolution of warm-up protocols from a long-term performance and injury-prevention standpoint

## 2. Materials and Methods

### 2.1. Study Design

This study was conducted as a randomized controlled pilot trial. Participants were randomly assigned to a *standard warm-up group* (SWG), which performed their usual warm-up routine, and to an experimental group (EG), which completed the shoulder-specific warm-up protocol developed by the investigators. Outcome measures were collected at two time points: at baseline, before the warm-up (T0), and immediately after warm-up (T1). This pre-post approach was used to assess the immediate responses to the warm-up and to identify short-term changes in joint mobility, neuromuscular control, and perceptual responses [17]. All assessments were conducted in the training environment where the athletes normally practice, in order to preserve ecological validity and minimize potential environmental influences. Testing was completed within a single session on the same day for each participant. The study design was chosen to reflect real-world training practice and to examine whether a targeted, shoulder-focused warm-up, compared with a habitual routine, could acutely enhance shoulder readiness for performance [18]. The underlying rationale was that a more specific warm-up may facilitate greater neuromuscular activation and joint preparedness, thereby supporting the execution of sport-specific movements in overhead sports [19].

## 2.2. Participants

A total of 24 youth competitive athletes (8 male, 16 female) voluntarily participated in this pilot study. Participants were randomly allocated to the SWG (n = 12), performing their habitual warm-up routine and the EG (n = 12), performing the strength- and mobility-based warm-up protocol proposed by the investigators. This was done randomly via the Wheel of Names software. All athletes were actively competing at an agonistic level and were training regularly at the time of data collection.

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Inclusion criteria were: (a) competitive athletic status; (b) age between 14 and 20 years; and (c) absence of current or recent upper-limb injuries, with specific reference to the shoulder complex. All participants were injury-free at the time of assessment, particularly with respect to the scapulohumeral joint. Written informed consent was obtained from the parents or legal guardians of all participants under 18 years of age prior to study participation.

The study was conducted according to the Declaration of Helsinki and was approved by the ethics committee of the University of Palermo 1, (Approval No. 325/2025), Department of Psychological, Educational and Movement Sciences, University of Palermo.

Anthropometric characteristics of the participants (age, height, and body mass) are reported as mean  $\pm$  standard deviation in Table 1.

**Table 1.** Anthropometric characteristics.

Variable	EG	SWG
Age (years)	14.67 $\pm$ 1.61	15.17 $\pm$ 1.53
Height (cm)	159.3 $\pm$ 7.08	158.9 $\pm$ 7.38
Body mass (kg)	49.58 $\pm$ 10.79	55.0 $\pm$ 12.49

**Notes:** Data are presented as mean  $\pm$  standard deviation (mean  $\pm$  SD); Height is reported in centimeters (cm) and body mass in kilograms (kg); EG: experimental group; SWG: standard warm-up group.

## 2.3. Assessment

All assessments were carried out in the athletes' usual training facilities at Palermo Sport & Performance and A.S.D. Azzurra Palermo, Italy. Conducting the evaluations in a familiar environment was intended to limit context-related influences on sensorimotor control and to obtain measurements that more accurately reflect the athletes' true performance capacity. Upon arrival, participants performed assessments at T0 using a fixed and standardized sequence: the Gyko inertial system (Microgate, Bolzano, Italy) was initially used to assess scapulohumeral joint range of motion. This was followed by the Handgrip strength test (KERN MAP Version 1.2 08/2012, Hand Grip Dynamometer) and, subsequently, by the Closed Kinetic Chain Upper Extremity Stability Test (CKCUES) [20–22]. Perceived exertion was assessed using the Borg CR-10 category-ratio scale (0-10). Participants were familiarized with the scale anchors and asked to rate their perceived effort immediately after completion of the warm-up protocol. In the present study, the Borg CR-10 score was used as an indicator of the internal load and perceived activation associated (e.g., perceived activation, satisfaction, and sense of shoulder freedom) with the preparatory stimulus [23,24].

After completion of the T0 assessments, participants-previously allocated to either the EG or SWG group performed their respective warm-up protocols. The EG completed the strength-based warm-up, whereas the SWG carried out their habitual warm-up routine. Immediately afterward, all participants performed the T1 assessment in the same order as at baseline. A detailed overview of the assessment tools, measured variables, and their intended purpose is provided in Table 2.

**Table 2.** Overview of assessment tools, measured variables, and study purposes.

Instrument	Variable Measured	Purpose	Administration Time
<i>Gyko</i>	Scapulohumeral joint range of motion	Used to quantify scapulohumeral joint flexion before and after the warm-up intervention	T0-T1
<i>Handgrip</i>	Maximal isometric grip strength	Used to assess baseline upper-limb strength and detect acute changes in force expression following the warm-up	T0-T1
<i>CKCUES</i>	Closed kinetic chain functional test assessing upper-limb performance through the number of hand touches performed within a fixed time interval	Used to evaluate shoulder stability and neuromuscular control before and after the warm-up	T0-T1
<i>Borg CR-10 (RPE)</i>	Perceived exertion score	Used to evaluate internal load experienced by the athlete, as well as the perceived level of activation elicited by the warm-up	T1

**Note:** CKCUES: Closed Kinetic Chain Upper Extremity Stability Test; RPE: Rating of Perceived Exertion; T0: before the warm-up; T1: immediately after warm-up.

#### 2.4. Warm-Up Protocols

##### 2.4.1. Strength-Based Warm-Up

The strength-based warm-up protocol was administered to the EG following a predefined and progressive sequence aimed at preparing the shoulder complex for overhead demands. Exercises were performed in the order reported in Table 3, and each exercise had to be completed before progressing to the next. The protocol began with self-myofascial release using a lacrosse ball applied to the pectoral region [25,26]. This initial phase was included to facilitate shoulder flexion mobility and to improve tissue readiness before subsequent movements and testing. Following myofascial release, athletes performed shoulder Controlled Articular Rotations (CARs). CARs consist of active, controlled, end-range rotational movements executed through the largest pain-free range of motion [27,28]. This exercise was included to promote active shoulder mobility, motor control, and joint awareness, supporting optimal scapulohumeral mechanics. The warm-up then progressed to Y-hurdle raises performed in a prone position on a bench inclined at 45°. From this position, athletes raised their arms in a Y-shaped pattern with the elbows extended, focusing on slow and controlled arm elevation. This exercise was included to enhance scapulohumeral control during shoulder elevation, with particular emphasis on the coordinated activation of the lower trapezius and serratus anterior. These muscles play a key role in optimizing scapular mechanics during overhead movements [29]. As the final exercise, the Y isometric hold was performed in a supine position. This exercise shared the same biomechanical objectives as the Y-hurdle raises but was executed isometrically. Athletes maintained the Y-shaped arm position while focusing on scapular retraction, upward rotation, and posterior tilt, minimizing compensatory movements [30]. The inclusion of an isometric contraction was intended to reinforce neuromuscular control and scapular stabilization at a joint position relevant to overhead activities [31,32].

All specific details regarding exercise volume, duration, and sequencing of the warm-up protocol are reported in Table 3.

**Table 3.** Strength- and mobility-based shoulder-focused warm-up protocol.

Exercise	Rounds	Duration / Reps	Rest
<i>Lacrosse ball release</i>	3	30'' Each side	No rest
<i>Shoulder CARs</i>	2	20 reps (10 forward +10 backward)	30''
<i>Y-Hurdle Raises</i>	2	20 reps	1'
<i>Y Isometric Hold</i>	3	20'' hold	20''

**Notes:** CARs: Controlled Articular Rotations; Rest: Recovery.

#### 2.4.2. Traditional Warm-Up

Participants assigned to the SWG performed their habitual warm-up routine, which reflected the exercises they typically use before regular training sessions. This approach was adopted to preserve and provide a realistic comparison with common practice. The traditional warm-up consisted of general activation and mobility exercises and was not specifically designed to target shoulder strength or scapular control [33]. Exercises were performed in the same order and manner routinely adopted by the athletes prior to training. A general overview of the exercises included in the traditional warm-up is reported in Table 4.

**Table 4.** Traditional warm-up routine.

Exercise	Rounds	Duration / Reps	Rest
<i>J.J.</i>	3	20 reps	30''
<i>Cat-Cow</i>	2	20 reps	30''
<i>Arms Mobility</i>	2	20 reps	30''
<i>Plank</i>	3	30'' hold	1'

**Note:** J.J: *Jumping Jacks*; Rest: Recovery.

#### 2.5. Statistical Analysis

Data are presented as mean  $\pm$  standard deviation (SD). The normality of data distribution was assessed using the Shapiro-Wilk test. For each outcome measure, a ANOVA (2x2) was performed, with group as the between-subjects factor and time (T0 vs. T1) as the within-subjects factor. When significant effects were detected in the ANOVA, Bonferroni-adjusted post hoc comparisons were performed. Effect sizes were reported as partial eta squared ( $\eta^2_p$ ). Statistical significance was set at  $p < 0.05$ . Borg CR-10 scores were only collected at T1 and were therefore analysed separately. Given the ordinal nature of the scale, differences between groups were assessed using the Mann-Whitney U test. Statistical analyses were performed using Jamovi software (version 2.3.21.0).

### 3. Results

As shown in Table 5, a significant difference was found in the ANOVA for right shoulder flexion ROM. Bonferroni post hoc analysis indicated a significant increase in the experimental group from T0 to T1 ( $p=0.008$ ). Whereas no significant difference emerged for the other variables. Borg CR-10 scores, reported in Table 6, were significantly higher in the experimental group at T1 ( $p=0.041$ ).

**Table 5.** Shoulder flexion range of motion, handgrip strength, and upper-limb functional performance. (mean  $\pm$  SD) in the experimental group (EG) and standard warm-up group (SWG) at baseline (T0) and post-warm-up (T1).

Parameters	Group	T0	T1	F	P	$\eta^2_p$
<i>S. Flexion L.</i>	EG	168 $\pm$ 7.55	172 $\pm$ 9.18	2.472	0.130	0.101
<i>Degrees (°)</i>	SWG	161 $\pm$ 8.83	162 $\pm$ 8.49			
<i>S. Flexion R.</i>	EG	160 $\pm$ 8.74	167 $\pm$ 9.03	11.63	<b>0.003*</b>	0.346
<i>Degrees (°)</i>	SWG	158 $\pm$ 9.91	156 $\pm$ 14.36			
<i>Handgrip L</i>	EG	21.8 $\pm$ 4.43	23.3 $\pm$ 4.55	0.0715	0.792	0.003
<i>(kg)</i>	SWG	27.8 $\pm$ 12.57	31.0 $\pm$ 10.96			
<i>Handgrip R</i>	EG	24.2 $\pm$ 4.87	25.2 $\pm$ 4.23	2.50	0.128	0.102
<i>(kg)</i>	SWG	30.9 $\pm$ 14.85	34.3 $\pm$ 12.42			
<i>CKCUES</i>	EG	15.8 $\pm$ 7.41	18.0 $\pm$ 9.27	0.0537	0.819	0.002
<i>(reps)</i>	SWG	18.5 $\pm$ 6.76	22.5 $\pm$ 5.57			

**Notes:** Data are presented as mean  $\pm$  standard deviation; T0: Baseline evaluation; T1: following warm-up protocol; L: Left; R: Right; S. Flexion: Shoulder flexion; CKCUES: Closed Kinetic Chain Upper Extremity Stability test; F, p, and  $\eta^2_p$  values refer to the time  $\times$  group interaction derived from ANOVA; \* Statistically significant difference ( $p \leq 0.05$ ).

**Table 6.** Borg CR-10 perceived exertion (median and IQR) in the experimental group (EG) and standard warm-up group (SWG) at T1.

Parameters	Group	T1	p-value
<i>Borg CR-10 (RPE)</i>	EG	7.25 (7.0-8.0)	<b>0.041*</b>
	SWG	6.75 (6.0-7.0)	

**Notes:** Data are presented as median and interquartile range (IQR). T1: post-warm-up assessment. p-value refers to the between-group comparison (Mann-Whitney U test; \* Statistically significant difference ( $p \leq 0.05$ )).

#### 4. Discussion

The present pilot study examined the acute effects of a shoulder warm-up focused on strength and mobility, compared with a usual routine, in young competitive athletes engaged in overhead sports. The main finding was a significant improvement in right shoulder flexion ROM in EG after the strength warm-up ( $p=0.008$ ). No significant effects emerged for handgrip strength or CKCUES performance. Borg CR-10 scores were also higher after the experimental protocol, suggesting a more pronounced perceived internal response to the preparatory stimulus. Overall, these findings indicate that a more shoulder-focused warm-up may produce an acute effect on a specific mobility outcome, while also modifying the athlete's subjective perception upon entering the subsequent phase of the training session.

The improvement observed in shoulder flexion ROM supports the hypothesis that incorporating controlled mobility exercises, scapular activation, and isometric stabilization into the warm-up may promote more specific preparation of the scapulohumeral complex before performance. This interpretation is in line with recent literature suggesting that warm-up strategies integrating mobility, scapular activation, and muscle engagement may provide more specific preparation of the shoulder complex in overhead athletes [34,35]. At the same time, recent studies have shown that even a single session of stretching or mobility-oriented work can improve range of motion, making the finding observed in the present study plausible within the context of a sport-specific warm-up [36,37].

From an applied perspective, this finding may be of interest because, in overhead sports, the mechanical load imposed on the shoulder complex is high and repetitive [38]. For this reason, the warm-up should not be considered merely a generic phase at the start of the session. Instead, it can be a valuable opportunity to prepare more specifically for the constant stress the nature of the sport subjects the structure to [39,40]. This does not replace strength work, prevention strategies, or

strengthening programs planned over the medium to long term, but it may represent an intelligent component within the periodization of accessory training.

In other words, optimising the warm-up means attempting to be more effective and efficient from the beginning of the session [41]. This is particularly important for young athletes, who often accumulate many training hours and for whom the practical sustainability of the proposed intervention is a central issue [42]. The recent literature on overhead athletes points in the same direction, highlighting how simple, specific, and low-cost programs may be useful both from a preventive perspective and in terms of shoulder function [43,44].

The absence of significant differences in the CKCUES test and the handgrip test may be plausible. With regard to the CKCUES, this is in fact a more complex test than an isolated measure of mobility, as it simultaneously involves upper-limb dynamic stability, trunk control, coordination, and muscular capacity. It is therefore reasonable to assume that a single exposure to the warm-up was sufficient to modify a specific parameter such as ROM, but not enough to generate equally evident changes in a more complex functional task [45]. This interpretation is also consistent with the most recent literature on the CKCUES, which acknowledges its usefulness and good psychometric properties, while also emphasizing the need to interpret its results in light of the multidimensional nature of the test and its measurement properties [46]. In a sample of already trained young athletes, this aspect may further reduce the likelihood of observing acute changes. A similar interpretation may also be proposed for handgrip strength. Although handgrip is a practical, rapid, and widely used test, it remains a relatively global measure and it may not be sufficiently sensitive in this context to detect subtle acute changes induced by a brief, shoulder-specific warm-up. A recent study recommended caution when interpreting handgrip strength as an indicator of general strength or functional performance, precisely because its associations with other strength measures are heterogeneous across different populations and contexts [47].

In our case, this consideration appears particularly relevant: given that the participants were young but already trained and sport-specific athletes, it is plausible that such a general test was not the most sensitive measure for detecting immediate changes after a single preparatory routine. In line with this caution, a recent study in overhead athletes showed that some differences in scapulohumeral function may not necessarily translate into changes in upper extremity dynamic stability or handgrip strength [48,49].

The Borg CR-10 findings add an important practical element to the interpretation of the present study. In our study, we used a scale to evaluate the athletes' perceived response to the warm-up. The score was then interpreted in relation to the athletes' immediate perceptions of activation, perceived preparedness, and an increased sense of shoulder mobility [50]. Within this framework, the higher values observed after the experimental warm-up do not appear to indicate fatigue severe enough to impair the immediate response to subsequent tests. Rather, they suggest greater perceived involvement and a higher level of readiness for the specific training session. This interpretation appears reasonable also because the higher perceptual response was accompanied by an improvement in ROM and not by a worsening of the other measured outcomes. Furthermore, recent literature continues to support the use of RPE as a valid, simple, and practical tool for monitoring internal load, an aspect that is particularly useful in youth settings, where tools must remain rapid, sustainable, and easily applicable in the field [51]. From a coaching perspective, this point is not secondary. In overhead sports, athletes are accustomed to working extensively on the shoulder complex, and it is by no means obvious that, after a warm-up, they will report a greater sense of freedom of movement and a favorable perception of the work performed [52,53]. Although this aspect was not collected using a separate validated instrument, it remains an interesting applied observation: a warm-up perceived as useful, that makes the athlete feel ready, and that is not experienced as "empty" work, is more likely to be accepted and maintained consistently over time. In this sense, the tested protocol appears to offer an interesting balance between specificity, tolerability, and immediate transferability to daily practice [19,54]. Overall, the present findings support the idea that warm-up design in overhead athletes should go beyond simple general systemic

activation and more accurately reflect the mechanical and neuromuscular demands placed on the shoulder complex [55].

## 5. Conclusions

This pilot study suggests that a shoulder-focused warm-up based on mobility, scapular activation, and isometric stabilization may be useful to acutely improve shoulder flexion ROM in young overhead athletes. In the present sample, the experimental protocol produced a significant improvement in right shoulder flexion, while no significant changes were found in handgrip strength or CKCUES performance. Athletes in the experimental group also reported a higher Borg CR-10 score after the warm-up, indicating a greater perceived response to the preparatory stimulus. Overall, these findings support the idea that, in overhead sports, warm-up routines may be effective when they are specifically designed around shoulder demands rather than based only on general activation. The contribution of this preliminary study does not lie in supporting a generalized improvement in all outcomes after a single session, but rather in showing that a targeted, manageable warm-up that can be easily incorporated into practice may acutely improve a relevant mobility parameter and be accompanied by a meaningful perceptual response in young athletes. For coaches and practitioners, this represents a concrete message: the warm-up is not merely a routine performed before training, but may become a genuinely useful part of preparation if constructed in a specific manner and aligned with the demands of the sport practiced [56,57].

The study also presents practical strengths: it was conducted in a real training setting, focused on a specific athletic population, and combined objective outcomes with a perceptual measure that is relevant to the daily work of coaches. Future studies, with larger samples and longitudinal designs, will need to clarify whether repeated exposure to this type of shoulder-focused warm-up may translate into broader improvements in shoulder function, sport-specific readiness, and long-term load management.

## 6. Limitations

This study presents some limitations that should be considered when interpreting the findings. First, the relatively small sample size and the acute design of the intervention may limit the generalizability of the results. However, the pilot nature of the study was intended to provide an initial exploratory evaluation of the proposed warm-up strategy in a real-world athletic context.

In addition, although functional performance measures were included, the absence of electromyographic and detailed kinematic analyses prevents a more comprehensive understanding of the neuromuscular mechanisms underlying the observed responses. Finally, the participants were young competitive athletes with relatively high baseline functional levels, which may have reduced the magnitude of short-term observable changes.

Future studies involving larger cohorts, longitudinal designs, and integrated neuromuscular assessments are warranted to further clarify and extend these preliminary findings.

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**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data are available on reasonable request from the corresponding author.

**Generative AI statement:** The authors declare that no Gen AI was utilised in the creation of the manuscript. AI-assisted technologies were employed solely to improve the readability and language of the manuscript. All modifications were carried out under human supervision, with the authors carefully reviewing every change.

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## Abbreviations

The following abbreviations are used in this manuscript:

ROM	Range of Motion
RPE	Rating of Perceived Exertion
CARs	Controlled Articular Rotations
EG	Experimental Group
SWG	Standard warm-up group
CKCUES	Closed Kinetic Chain Upper Extremity Stability Test
SD	Standard Deviation
IQR	Interquartile Range
T0	Baseline Assessment
T1	Post-Warm-Up Assessment

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