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Joint mobility limitations and fundamental motor skills in adolescents participating in a weight training program
Limitările mobilităţii articulare şi deprinderile motrice de bază la adolescenţii supuşi unui program de forţă

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Abstract

Background. Fundamental Motor Skills have been developed as an integral part of the Health and Physical Education Curriculum Planning and Course Support materials documentation. Fundamental motor skills, such as overhand throw, underpin the learning of more complicated sport and movement skills common to the community. It is generally believed that the range of motion (ROM) has a significant role in the performance of movements.

Aims. The present study aims at observing the role of weight training exercise on decreasing the ROM and its relation with kinematical aspects of the movement pattern performance.

Methods. To do so, the performance of overhead throwing was compared between weight training participants (WT) and non-weight training participants (NW).

Results. The analysis of the data showed that the ROM of internal and external rotation of the shoulder was lower in WT than in NW subjects ($P<0.05$). There were also significant differences in the angular displacement of the shoulder ($P=0.049$) and elbow ($P=0.045$) between the two groups of subjects. Furthermore, the movement pattern of the WTs was not consistent with the open kinetic chain principle.

Conclusions. The results show that the performance of WTs in the overhead throwing pattern was less efficient in comparison with that of NWs. So, it can be concluded that weight training has a negative effect on one of the fundamental motor skill performances due to the decrease in joint mobility.

Key words: flexibility, performance, weight lifting, hypertrophy.

Rezumat

Premize. Deprinderile motorii de bază au fost dezvoltate ca parte integrantă din materialele documentare suport pentru cursul intitulat Planificarea în Sănătate şi Educaţie Fizică. Deprinderile motorii de bază, printre care şi aruncarea de deasupra capului, stau la baza învăţării mişcărilor şi deprinderilor sportive mai complexe. Se consideră în general că amplitudinea mişcării (AM) are un rol semnificativ în execuţia mişcărilor.

Obiective. Studiul de faţă şi-a propus să identifice efectul de reducere al AM, pe care-l au exerciţiile cu greutăţi, precum şi impactul acestui efect asupra kinematicii mişcărilor.

Metode. În acest scop, un grup de subiecţi supuşi unui antrenament de forţă a fost comparat cu unul martor, în ce priveşte execuţia aruncării de deasupra capului.

Rezultate. Analiza datelor a arătat că amplitudinea mişcărilor de rotaţie internă şi externă a umărului era mai scăzută la subiecţii supuşi antrenamentului de forţă ($p<0,05$). Deplasarea unghiulară a umărului ($p=0,049$) şi cotului ($p=0,045$) au fost şi ele semnificativ diferite, la cele două grupuri de subiecţi. În plus, pattern-ul mişcărilor celor incluşi în antrenamentul de forţă nu se conforma principiului lanţurilor kinetice deschise.

Concluzii. Rezultatele indică faptul că pattern-ul execuţiei aruncării de deasupra capului este mai puţin eficient la subiecţii supuşi antrenamentului de forţă, decât la ceilalţi subiecţi. Ceea ce conduce la concluzia că antrenamentul de forţă are un efect negativ asupra acestei deprinderi motorii de bază, ca urmare a reducerii mobilităţii articulare.

Cuvinte cheie: flexibilitate, execuţia mişcărilor, antrenamentul cu greutăţi, hipertofie.

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Introduction

Range of motion means the ability of joints to perform motions before getting limited due to the structure of the bones, ligaments or the surrounding muscle mass (***, 2005; Norkin & White, 1995). The physical requirements and special movement patterns in professional athletes lead to a kind of maladaptation of their musculoskeletal system (Crockett, 2002). These changes appear as a decrease in ROM, a change in biomechanical patterns, a decrease in the efficiency of force production, an increase in the possibility of musculoskeletal injuries and faulty posture (Chandler et al., 1990). Although faulty posture is not necessarily a disorder, it can lead to a decrease in optimum body mechanics (Ackland et al., 1995). Therefore, using the joints and muscles in special movement patterns and situations in the long term may shorten and stiffen the muscle tissue surrounding the joints and finally decreases the ROM (Daneshmandi et al., 2010).

Weight training is employed in many sports aiming at increasing power, strength and at decreasing the possibility of injury (***, 2001). The exercise conditions in these sports are the way that the athletes are going to acquire more power and strength through hypertrophy (Chiu & Schiling, 2005). Most of the athletes who lift weights unconsciously focus on increasing the power of pectoralis, deltoid and abdominal muscles and forget to increase the strength of the stabilizer muscles of shoulder joints (Barlow et al., 2002). Furthermore, the increase in muscle mass has been recognized as one of the main factors of decreased ROM, of dynamic shoulder instability in bodybuilders, reducing shoulder ROM in abduction and internal rotation in weightlifters, as shown in previous studies (Calhoon & Fry, 1999; Kolber et al., 2009; Kolber & Corrao, 2011; Kordi et al., 2013). Recent surveys have shown that the decrease in the internal and overall rotation of the shoulder may have a negative impact on the motor performance of the shoulder joint, i.e. through creating biomechanical inefficiency, it decreases the movement of the arm (Wilk et al., 1997). Moreover, it has been seen that the decrease in ROM can lead in the long term to the decrease in sport performance (Chandler et al., 1990; Hall & Martin, 2002).

It is generally believed that ROM has a significant role in the proper performance of many life activities (***, 2005). For example, Jelsma et al. (2013) showed a relationship between joint mobility and motor performance. People who have decreased ROM in their shoulders have difficulties in doing many activities of the daily life such as donning and doffing clothing, overhead movement, reaching and rotation activities (Hannafin & Chiaia, 2000), so that as a result of this inability, they cannot carry out physical and other social activities efficiently (Tovin & Greenfield, 2001).

The benefits and damages caused by weight training date back to many years ago (Chiu & Schilling, 2005). Although previous studies showed that weight training leads to a decrease in ROM and that ROM limitation affects motor performance, the majority of these studies focused on the relationship between ROM and motor performance in persons with motor disabilities such as developmental coordination disorder, Parkinson disease or autism spectrum disorders (Jelsma et al., 2013). So, the main question of the present study is whether or not there is any relation between limited joint mobility and performing one of the most important motor skills such as the overhand throwing pattern. This is important because overhand throwing is one of the fundamental motor skills that are used in sports and movement activities. For example, throwing in softball and cricket, the baseball pitch, the javelin throw, the tennis serve and the netball shoulder pass are all advanced forms of the overhand throw. The presence of all or part of the overhand throw can be detected in the patterns used in these sport specific motor skills (Payne & Isaacs, 2005). The Open Kinetic Chain (OKS) is used to describe the pattern of the throwing movements. According to this principle, different body segments are linked to each other like a linkage, when the distal end is free to move, the proximal end is fixed (Lee & Chen 2004).

Hypothesis

Therefore, we are going to answer the following questions: a) Is there any relationship between ROM and kinematic aspects of the overhand throwing pattern, and b) Whose kinematic pattern of overhand throwing is closer to OKS: that of weight training participants (WTs) or of non-weight training participants (NWs)?

Material and methods

Research protocol

We mention that according to the Helsinki Declaration, the Amsterdam Protocol and Directive 86/609/EEC, the approval of the Ethics Commission of the Medical University of Arak was obtained. The research procedures were explained to all the study participants and an informed consent was also obtained from all patients prior to the study.

a) *Period and place of the research*

The study took place between October 2012 and October 2013 at the biomechanical center of The National Olympic Academy of Iran, Tehran, Iran.

b) *Subjects and groups*

The studied samples were 23 healthy men aged 12-15 years old, who were distributed as follows: ten weight training participants in the experimental group, ten non-weight training participants in the control group, and three baseball players in the reference group.

In order to create the reference pattern, three elite baseball players with the mean age of (14.41±1.23), matched with WTs and NWs were used. The mean age of the WT group was (13.43±1.13) and that of the NW group was (13.33±2.57). The WTs in this study were athletes who had had 3 regular exercise sessions a week for at least 3 years (Barlow et al., 2002) and the NWs were ordinary people who had had no weight training during their lifetime. All participants were right handed and had no sign of muscular skeleton injury or pain in their body one month before participating in this study. All participants took part in this research voluntarily. This study was approved by the Ethical Committee of the Tehran University of Medical Sciences.

c) *Tests applied*

According to Norkin & White (1995), the internal rotation (IR) and external rotation (ER) of the shoulder's passive ROM was measured by a standard Baseline goniometer. All the measurements were done in the morning, after a 15 minute warm-up program; this program consisted of 3 active stretches, according to Barlow et al. (2002). To measure IR and ER of the shoulder, the humerus was positioned at 90° and the elbow was in flexion at 90°, while the subjects were lying supine. Then, the participants were required to conduct the rotation up to the end of ROM. After that, the rotation was recorded. The measurement was done for both the dominant and non-dominant sides of the participants (Norkin & White, 1995).

The images of the performance were recorded with a camera (250 Hz, 1/2000s), in two dimensions, from the right side for all the participants. The reflective markers were placed on the superior tip of the acromion, lateral humeral epicondyle, ulnar and radial styloid, distal end of third metacarpal (Fleisig et al., 2006). In an explanatory meeting, the individuals were familiarized with the purpose of the study and the way the movement pattern was performed.

In the beginning, the modeling and verbal instructions were done through the performance of a semi-skilled individual, showing film, picture and verbal explanations on the pictures (Schmidt & Wrisberg, 2004). The verbal explanations provided general information about preliminary aspects of movement skill, such as the standing position, how to catch and throw the ball. Then, the participants tried to perform the overhand throwing in three trials (Lee & Chen, 2004). In this study, the OKS principle of the participants was investigated based on velocity graphs of the shoulder, elbow and wrist joints. Filming the baseball players to construct the reference pattern was also done in the same way.

In the present study, the Edinburgh Handedness Inventory was used in order to determine the dominant hand and the Nordic questionnaire for musculoskeletal injuries was used to guarantee the absence of injuries in the participants. The validity and reliability of the Handedness Inventory (Williams, 1991) and Nordic questionnaire (Kuorinka et al., 1987) have been reported as acceptable. Also, the shoulder circumference was measured using a tape measure, based on the method proposed by Heyward (2006), which was conducted on the right side of the participants. To do so, the tape was applied snugly over the maximum bulges of the deltoid muscle, inferior to the acromion processes for shoulder girth.

d) *Statistical processing*

Being assured of the data normality with the Kolmogorov-Smironov test, to compare the ROM between the WT and the NW group, the independent t-test was used. In order to process kinematical data, the final images were put into the motion analysis software (Winanalyze 4). Then, to analyze the kinematical data, they were put into Excel (2007) to draw the graphs related to the velocities of different joints. Furthermore, using the SPSS software, the data analysis was done by independent t-tests, MANOVA, ANOVA, LSD and Pearson correlation coefficient.

Results

All participants were right handed. The data related to the age and body composition of the two groups (WT & NW) showed no significant differences in age (P=0.36), body weight (P=0.42) and shoulder circumference between the groups (P=0.25). Yet, significant differences in height were observed (P=0.021).

Passive ROM

The results indicated that the passive ROM in IR and ER in the dominant and non-dominant side was significantly (P<0.05) lower in the WT group than in the NW group (Table I).

Kinematical features

The comparison of the kinematical features of angular displacement in three joints; shoulder, elbow and wrist among WT, NW and elite baseball players (reference group) was performed using the MANOVA test. The result of Wilks' lambda test showed that there was a significant statistical difference (F=5.818, P=0.002, partial $ŋ^2$=0.853) between the three groups in the feature of angular displacement of the serve skill performance. The result of the ANOVA test suggests a significant difference in the feature of angular displacement of the shoulder (F=5.168, P=0.031) and elbow joint (F=14.154, P=0.001) between the three groups.

Next, for comparisons among the groups regarding two features of angular displacement of the shoulder and elbow, the LSD test was used. The results are shown in Table II. The movement pattern of the WTs in the angular displacement of the shoulder (P=0.049) and elbow (P=0.045) evidences a significant difference compared to the reference pattern. However, there was no that difference in the serve skill performance between the NW pattern and the reference pattern (P>0.05).

In Figure 1(a), the velocity graph of one of the reference group's members (M_1) is shown, in Figure 1(b), one of the WT's (E_3) and in Figure 1(c), one of the NW's (N_8) are shown.

Table I

Comparison of the mean ROM score between weight training participants and non-weight training participants.

Variables		Mean	t	sig.	Mean difference
Dominant internal rotation	Weight training Non-weight training	39.33±13.48 58.00±12.00	18.666	0.03*	2.533
Non-dominant internal rotation	Weight training Non-weight training	37.00±11.57 57.33±9.68	20.333	0.008*	3.299
Dominant external rotation	Weight training Non-weight training	64.83±9.88 94.00±15.28	26.166	0.003*	3.925
Non-dominant external rotation	Weight training Non-weight training	62.33±7.20 90.33±14.71	28.000	0.002*	4.185

* Differences are significant at the 0.01 level (2-tailed)

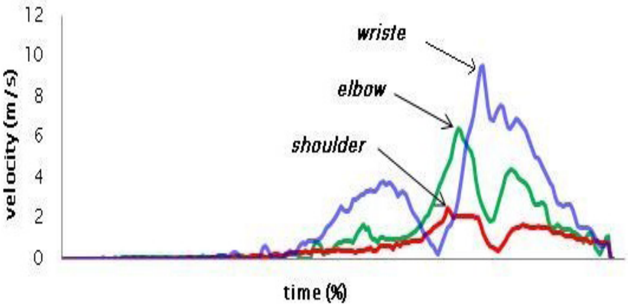

Fig. 1(a) – Velocity variation of M_1 joint (reference group).

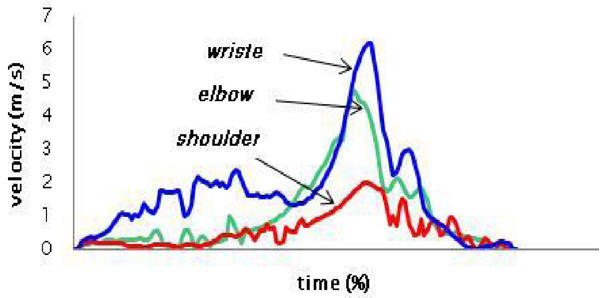

Fig. 1(b) – Velocity variation of E_3 joint (weightlifter group).

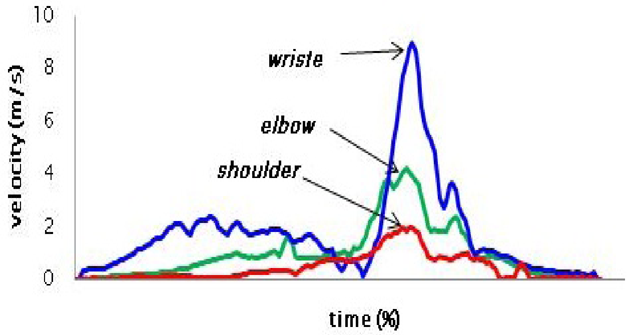

Fig. 1(c) – Velocity variation of N_8 joint (non-weightlifter group).

As it can be seen, in the graph related to the reference participant M_1, first the shoulder, then the elbow and the wrist joint velocity reached their peak, which is completely in line with the OKC principle (Lee & Chen, 2004). However, in the case of the weight training participant E_3, first the elbow, then the shoulder and the wrist joint velocity reached their peak, which does not comply with the OKC principle (Figure 1.b vs. 1.a). As for the non-weight training participant N_8, the peak of the velocity for the shoulder and elbow respectively occurred within a short time distance and subsequently, the wrist joint velocity reached its peak (Figure 1.c). Although the performance of the mentioned participant N_8 was not similar to that of the reference individual M_1 (Figure 1.c vs. 1.a), it was closer to the OKC principle compared to participant E_3.

ROM and the movement kinematics

The correlation between the passive ROM of the IR and ER of the shoulder in the participants and their shoulder and elbow joint displacement indicated the existence of a positive and significant correlation between IR and the shoulder angular displacement (r=0.659, P=0.02), and also between ER and the elbow angular displacement (r=0.626, P=0.029) in the serve skill performance (Table III).

Discussions

The present research was aimed at observing the role of deficient ROM on the kinematical features of performing a fundamental movement pattern in adolescents participating in weight training. To do so, the performance of the overhead throwing pattern was observed in individuals having the experience of weight training and non-weight training (ordinary people or control group). At first, it was observed that the ROM of WTs in their shoulder IR and ER was lower than that of NWs ($p<0.05$). The present result is in line with the findings of previous studies performed on weightlifters (Barlow et al., 2002; Calhoon & Fry, 1999; Chang et al.1988; Kolber et al., 2009; Kolber & Corrao, 2011; Kordi et al., 2013). Barlow et al. (2002) observed that the ROM of bodybuilders in the shoulder IR and ER was lower compared to the control group. Also, another study indicates that compared to ordinary people, the ROM of power lifters is lower (Chang et al., 1988). Furthermore, Kolber and Corrao (2011) and Kolber et al. (2009) found that the ROM of male and female recreational weight

Table II

Comparison of the kinematical features of shoulder and elbow angular displacement between the groups.

Dependent variable	Group		Mean difference	Sig
Shoulder angle displacement	Weightlifters	Non-weightlifters	-23.958	0.111
	Weightlifters	Reference	-38.213*	0.049
	Non-weightlifters	Reference	14.254	0.630
Elbow angle displacement	Weightlifters	Non-weightlifters	-36.595*	0.001
	Weightlifters	Reference	-27.269*	0.045
	Non-weightlifters	Reference	9.325	0.626

* Differences are significant at the 0.05 level (2-tailed)

Table III

Correlation coefficient between ROM of internal and external rotation and angular displacement of the shoulder and elbow joints.

	Internal rotation	External rotation	Shoulder angle displacement	Elbow angle displacement
Internal rotation	1			
External rotation	0.377	1		
Shoulder angle displacement	0.659*	0.525	1	
Elbow angle displacement	0.465	0.626*	0.662*	1

training participants in their shoulder internal and external rotation was significantly lower than in the control group. In previous studies, the increase in muscular mass (Barlow et al., 2002; Calhoon & Fry, 1999), posterior shoulder tightness in weightlifters (Corrao et al., 2009; Kolber et al., 2009), muscular skeletal maladaptation due to repeated demands, particularly on ROM (Daneshmandi et al., 2010), and the unfavorable position of shoulder under heavy loads for long time periods (Corrao et al., 2009; Kolber et al., 2009; Kolber & Corrao, 2011) are mentioned as the most important factors of deficient ROM. Posterior shoulder tightness combined with muscular imbalance and hypertrophy may be responsible for the decrease of overall shoulder ROM in weight training participants (Kolber et al. 2009).

It was also observed that the kinematical features of angular displacement of movement were significantly different among the WT, NW and the reference pattern (F=5.818, P=0.002). The result of the LSD test suggested that the angular displacement of the shoulder (P=0.049) and elbow joint (P=0.045) in the WT group was significantly lower than that of the reference group. However, no significant difference was found between the angular displacement of the shoulder (P=0.630) and elbow (P=0.626) in the NW group compared to the reference group.

One of our observations was related to the change in the joint velocity while performing the overhead throwing pattern. According to the OKC principle for overhand throwing patterns, first the proximal and then the distal segments of the body perform the motion. Therefore, the shoulder, elbow and wrist respectively must reach their highest velocity (Lee & Chen, 2004). As observed through the comparison of the graphs related to the variations in the velocity of the shoulder, elbow and wrist motion of the participants (M_1-E_3-N_8) the WTs' performance was not based on the OKC principle (Figure 1.a), but the NWs' performance was closer to OKC (Figure 1.b). As a result, it can be said that the performance pattern of the NW group (N_8, see Figure 1.c) was better than that of the WT group (E_3).

Generally, the relation between ROM and movement disabilities has been investigated by Dunlop et al. (1998), who implicitly point to joint impairment as an indication of future disability. ROM deficit leads to a decrease in the ability of performing physical activities and other effective behaviors and consequently, to the functional limitation of the individuals (Tovin & Greenfield, 2001). Impaired posture and impaired muscle performance have been mentioned among the causes of shoulder ROM deficit. Generally, weight training exercises cause the shoulder to get in an unfavorable position such as end-range ER (Kolber & Corrao, 2011). Also, most of the weight training upper extremity exercises focus on increasing the mass and strength of the big muscles and ignore the smaller ones that have the role of stabilizing the shoulder (Barlow et al., 2002; Kolber et al., 2009), which has been recognized as leading to shoulder impairment (Haupt, 2001; Neviaser, 1991), shoulder motor imbalance (Kolber & Corrao, 2011) and posterior shoulder tightness (Corrao et al., 2009; Kolber et al., 2009; Kolber & Corrao, 2011). While the ordinary performance of the shoulder requires a fine balance between the strength and mobility of muscle groups which are supposed to act synchronously (Kolber & Corrao, 2011), weight training exercise which is performed based on special muscle groups generally ignores the balance between strength and mobility required for the appropriate function of the shoulder (Kolber et al., 2009). Also, joint kinetics has an essential role in the velocity of overhead movements (Bergün et al., 2009). Takahashi et al. (2000) showed that finger and wrist flexibility plays an important role in performing kinematical features. Therefore, these could be the reasons for the difference between the WTs' performance pattern and the OKC principle.

Finally, the result of the Pearson correlation test indicated a significant and positive relationship between the ROM of shoulder IR and the shoulder joint angular displacement, between ER and the elbow joint angular displacement ($P<0.05$). On the other hand, the participants who had a higher ROM in shoulder IR and ER had a higher joint angular displacement in the serve skill performance. Therefore, people who had a lower passive ROM also had a lower angular displacement of the joints. Moreover, Brown et al. (2000) found that ROM deficit is one of the factors creating physical frailty. As it was seen, the ER of the shoulder was significantly correlated with the physical performance test. Also, it is said that there is a strong correlation between ROM and arm performance (Bland et al., 2008). For example, limiting ROM of the shoulder decreases the arm performance in young healthy individuals (Bland et al., 2008). Accordingly, it can be said that the mentioned results are in accordance with other study findings.

Conclusions

1. The important point in this research was observing the closeness of movement patterns of ordinary participants to those of the reference group, i.e. ROM deficit following heavy weight training can cause inefficiency in performing the overhead throwing movement pattern in WTs.
2. This issue is noteworthy when we get to know that this pattern is related to many sport skills. Also, it can be predicted that the performance pattern of WTs is not appropriate for other overhead throwing skills. Therefore, we suggest the further investigation of this issue in future studies. It should be mentioned that the small sample size and the two-dimensional analysis of the motions were the limitations of the present study. Hence, it is suggested that the results of the present study be generalized with caution.

Conflicts of interest

There are no conflicts of interest.

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