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Accuracy of Pinch Force Sense in Elite Female Adolescent Weightlifters

Elit Kadın Adolesan Haltercilerde Parmak Sıkıştırma Kuvvet Duyusunun Keskinliği

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ABSTRACT

Objective: Force sense is an aspect of proprioception, which is most commonly assessed by reproducing a percentage of maximal voluntary isometric contraction. Exercise improves other aspects of proprioception such as joint position sense and kinesthesia, but there are contradictory findings regarding the effects of exercise on force sense. The purpose of this study is to assess the effects of long-term weightlifting training on pinch force sense of elite adolescent female athletes.
Materials and Methods: Maximum key and tip pinch strength of 25 elite female adolescent weightlifters and 22 sedentary peers were measured. Participants were asked to press the pinchmeter with 50% of their maximal strength 3 times while looking at the scale and try to learn how much force they apply. Participants then tried to reproduce 50% of their maximum key and tip pinch strength without any visual feedback 3 times. Absolute error, constant error, root mean square error and coefficient of variation were calculated and these values were normalized by dividing to the target values. Accuracy was evaluated by absolute error and root mean square error; directionality of errors was evaluated by constant error and the precision was evaluated by coefficient of variation.
Results: Weightlifter adolescents had higher key and tip pinch strength values compared to sedentary ($p=0.03$ and $p=0.02$, respectively). Normalized absolute error was lower in weightlifters in comparison with sedentary in both key and tip pinch force sense ($p<0.01$).
Conclusions: These results demonstrate that regular weightlifting training improves accuracy in pinch force sense, without affecting precision or directionality of error. In future studies, it would be appropriate to investigate whether higher accuracy in force sense would also be evident in adult or senior weightlifters.
Key words: pinch strength, force sense, proprioception, weightlifting, adolescence

ÖZ

Amaç: Kuvvet duyusu, eklem pozisyon duyusu ve kinestezi ile birlikte propriyosepsiyonun bir bileşenidir. Maksimal istemli izometrik kontraksiyonun belli bir yüzdesinin tekrarlanabilme becerisi ile değerlendirilir. Egzersizin, eklem pozisyon duyusu ve kinesteziyi geliştirdiği bilinmesine rağmen kuvvet duyusu üzerindeki etkileri bilinmemektedir. Bu çalışmanın amacı adolesan elit kadın haltercilerin yaptığı egzersizlerin parmak sıkıştırma (pinch) kuvveti duyusu üzerine etkisinin olup olmadığını araştırmaktır.

Gereç ve Yöntem: Çalışmaya 25 elit kadın adolesan halterci ve 22 sedanter kadın akranı dahil edildi. Her bir katılımcının maksimum lateral ve iki nokta parmak sıkıştırma kuvveti değerleri pinchmetre kullanılarak ölçüldü. Katılımcılara bu değerin %50'sini oluşturacak şekilde pinchmetreye bakarak 3 kez sıkıştırmaları ve bu kuvveti öğrenmeye çalışmaları istendi. Daha sonra katılımcılardan herhangi bir görsel geribildirim almadan 3 kez daha aynı hedef kuvveti oluşturmaları istendi. Elde edilen ölçümlerden mutlak hata, ortalama hata kareleri kökü, varyasyon katsayısı, sabit hata hesaplandı. Her bir parametre hedef değere oranlanarak normalize edildi. Karşılaştırmalarda normalize değerler kullanıldı. Mutlak hata ve ortalama hata kareleri kökü denemelerin doğruluğunu; varyasyon katsayısı tutarlılığını; sabit hata ise hatanın yönünü değerlendirmek için kullanıldı.

Bulgular: Haltercilerin lateral ve iki nokta parmak sıkıştırma kuvveti değerleri sedanterlere kıyasla daha yüksek (sırasıyla *p=0.03* and *p=0.02*), normalize edilmiş mutlak hata değerleri ise daha düşük olarak bulundu ($p<0.01$).

Sonuçlar: Bu sonuçlar, düzenli halter antrenmanının adölesanlarda parmak sıkıştırma kuvvetini artırdığını, ayrıca hatanın tutarlılığını ve yönünü etkilemeden, parmak sıkıştırma kuvveti duyusunun doğruluğunu geliştirdiğini göstermektedir. Gelecek çalışmalarda genç sporcularda gözlemlenen kuvvet duyusundaki yüksek doğruluğun, yetişkin veya yaşlı haltercilerde de olup olmadığını araştırmak uygun olacaktır.

Anahtar sözcükler: Parmak sıkıştırma kuvveti, kuvvet duyusu, propriyosepsiyon, halter, adolesan

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INTRODUCTION

Proprioception is defined by Buzzard as the "sixth sense". A more precise definition would be "the sense of posture, movement and changes in equilibrium, and the knowledge of position, weight, and resistance of objects in relation to the body"(1). Proprioception in general is affected by age, injury, chronic conditions and exercise training (2). Although exercise is known to improve proprioception, whether this improvement is a result of peripheral adaptation, neural plasticity or both remains unknown (3). Force sense is one of the three aspects of proprioception, together with joint position sense and kinesthesia; and it is most commonly assessed by reproducing a percentage of maximal voluntary isometric contraction (4,5). Force sense evaluates one's ability to detect muscle tension. Accuracy in controlling muscle tension may help athletes to fire muscles when necessary and potentially decrease the chance of injury (6). Although training has beneficial effects on proprioception in general, the effects of training on force sense is not clear due to contradictory findings in the literature. For instance, in Smith and coworkers' study, it was found long-term gymnastic training improved force sense of elbow flexors (7); however in Netscher and coworkers' study, patients with ankle instability failed to improve their ankle force sense following a 6-week training program (6).

Joints and movements through which force sense can be measured include but are not limited to ankle, shoulder, knee, handgrip, and pinch strength. Pinch strength is a frequently tested parameter in patients with entrapment neuropathies or traumatic hand injuries (8,9). It is a reliable test measure that establishes a baseline from which to evaluate improvement, assess the efficiency of treatment and set individual goals for each patient (10).

Weightlifting is associated with higher risk of neuropathies at the shoulder, elbow and wrist; such as suprascapular nerve entrapment, musculocutaneous nerve palsy, entrapment of the distal posterior interosseous nerve, cubital tunnel syndrome and carpal tunnel syndrome (11–13). Among these neuropathies, in carpal tunnel syndrome the median nerve is entrapped and the pinch strength is impaired. Weightlifters flex and extend the wrist excessively during training and the hypertrophy of the lumbricals is also associated with median nerve compression in weightlifters (14). Therefore, weightlifters are considered as a risk group for median neuropathy and pinch strength is of special importance in this population, because the target pinch

force in the treatment of median neuropathy should be different among weightlifters.

Whether force sense measures of weightlifter adolescents are different than sedentary peers is not clear. In this regard, the purpose of this study is to assess the effects of long-term elite-level weightlifting training on pinch force sense.

METHODS

This study was approved by Local Ethics Committee (Project number: 2018/1584). Written informed consents were obtained from all individual participants and legal representatives of minors.

Participants

In total, 47 right-handed healthy subjects (25 female weightlifters and 22 female sedentary peers) participated in the study. Mean age of weightlifters was 16.4 ± 1.63 years, and control group was 15.7 ± 0.45 years.

Female adolescent weightlifters who have been training regularly for at least 4 years and competed at national and/or international level were recruited for the research. Athletes regularly trained 5 days a week, 3 hours a day at minimum. A typical weightlifting training session of the athletes included snatch, clean& jerk, front full squat and snatch drop movements. Sedentary controls of the same age and sex were also invited to the study as a control group. Participants who suffered from an injury related to hand, wrist, elbow or shoulder within 3 months prior to study were excluded. Also, exercising regularly was an exclusion criterion only for control group.

Anthropometrics and Hand Dominance

Height was measured barefoot using a portable stadiometer with a precision of 0.1 mm (Seca 206, Germany) and body weight was measured by a digital scale (WB-800S plus, Tanita Corporation, Japan). Body mass indexes were calculated accordingly. Demographics and anthropometrics of participants are given in Table 1.

Table 1: Demographic and anthropometric characteristics of weightlifters and sedentary controls. Data is displayed as "mean ± standard deviation".

	Weightlifters	Sedentary	p value
N	25	22	
Age (years)	16.40 ± 1.63	15.72 ± 0.45	0,09
Height (m)	1.60 ± 0.07	1.64 ± 0.05	0.047*
Mass (kg)	58.69 ± 12.50	56.27 ± 7.93	0,84
Body mass index (kg/m²)	22.64 ± 3.65	20.84 ± 2.41	0,06

Hand dominance of participants were determined by Edinburgh Inventory (validated Turkish version) (15) and Geschwind score. Questions in the inventory were scored as -10, -5, 0, +5, +10, respectively and total scores between -100/-40 were considered left-handed, between -35/35 were considered both-handed and scores between +40/+100 were considered right-handed (16). Only dominant hands were used in the research.

Pinch Strength Measurement

Tip (two-point) pinch and key (lateral) pinch strength of participants were measured by Baseline™ Evaluation Instruments - Hydraulic Pinch Gauge. Subjects were seated with their shoulder adducted, in neutral rotation, elbow at 90° of

flexion, and forearm in neutral position as described by Mathiowetz et al (17). Descriptions of the American Society of Hand Therapists were adopted and used as described in the work of Mathiowetz *et al.* in this study. Hence, key (lateral) pinch is defined as pad of the thumb against the radial side of the index finger between the distal and proximal interphalangeal joint; whereas tip pinch is defined as thumb tip to index finger tip (10,17). Dynamometer was held lightly by the examiner to keep the instrument in correct position. Participants were instructed to squeeze the instrument as hard as possible for three consecutive times and the best result was recorded as maximal strength.

Force Sense Measurement

Target force was established as 50% of the maximal key and tip pinch strength for force sense measurements and participants were instructed to squeeze the instrument only to this individual target force value guided by visual feedback. They were allowed to repeat three times under visual feedback and were informed that they will be asked to reproduce the same force without any visual feedback afterwards. Three trials of reproducing 50% of the maximum strength (without visual feedback) were recorded.

Data Analysis

Accuracy in force sense was evaluated with absolute error (AE) and root mean square error (RMSE). Directionality of reproduced forces in relation to target load (under-/overshooting) was evaluated with constant error (CE). Precision in reproducing the target load was evaluated with the coefficient of variation (CV). Absolute error is the average of the absolute values of each trial error. Coefficient of variation is the ratio of the standard deviation to the mean. Constant error and root mean square error are calculated according to Formula 1 and Formula 2, respectively. Normalized versions of constant error (nCE), absolute error (nAE), and RMS errors (nRMSE) were calculated by (Error/Target Load*100). Only normalized errors and coefficient of variation were used for comparisons between groups.

Formula 1:

$$\text{Constant Error} = \left(\sum_{i=1}^{n} (X_i - X_{target})\right) / n$$

Formula 2: Root Mean Square Error =

$$\sqrt{\left(\sum_{i=1}^{n} (X_i - X_{target})^2\right)/n}$$

Normality of the data distribution was tested by density plots, histograms and Shapiro-Wilk test. Descriptive statistics were used to analyze the demographic characteristics of participants. Student's t test for normally distributed data and Wilcoxon rank-sum test were used for inferential analyses of non-normally distributed data. The level of significance was set at $p < .05$. All analyses were performed using R software, version 3.5.1(18).

RESULTS

The maximum key and tip pinch strength values of weightlifters and sedentary adolescents are displayed in Table 2. Maximum key and tip pinch strengths of weightlifters were significantly higher than of sedentary peers (*p=.03* and *p=.02*, respectively).

Values of AE, nAE, CE, nCE, RMSE, nRMSE, and CV for key and tip pinch force sense of weightlifters vs. sedentary controls are presented all together in Table 3. Also, nAE values of key and tip pinch force sense are shown graphically in Figure 1 and 2, respectively.

Weightlifters displayed less nAE in both key and tip pinch force sense compared to sedentary ($p<0.01$, both.) (Table 3, Figure 1, Figure 2).

Table 2: Maximum key and tip pinch strength values of weightlifters and sedentary adolescents.

	Weightlifters	**Sedentary**
Key pinch, kg	6.8 ± 1.02	6.0 ± 1.02 *
Tip pinch, kg	4.3 ± 1.24	3.6 ± 0.75 *

* Significantly different than weightlifters *(p<0.05).*

Table 3: Key and tip pinch force sense errors of weightlifters vs sedentary controls. (Data with a normal distribution is presented as mean ± standard deviation, whereas data with a non-normal distribution is presented as median value with interquartile range.) *Significantly different from sedentary *(p<0.01).*

	Key pinch		Tip pinch	
	Weightlifters	**Sedentary**	**Weightlifters**	**Sedentary**
Absolute Error	0.8 (0.83)	1.2 ± 0.62	0.7 (0.66)	1.0 (1.29)
Normalized AE	9.3* (11.90)	15.2 (19.40)	16.7* (15)	31.6 ± 16.01
Root Mean Square Error	1 ± 0.65	0.8 ± 0.33	0.8 (0.61)	0.9 ± 0.49
Normalized RMSE	13.1 ± 7.82	9.8 (8.93)	20.0 (13.62)	20.1 ± 8.82
Constant Error	-0.5 (0.98)	-0.5 ± 1.27	0 (1.17)	0.1 ± 1.61
Normalized CE	-2.6 ± 12.51	1.4 ± 26.99	-11.1 ± 23.42	-10.9 ± 33.65
Coefficient of Variation	0.1 ± 0.05	0.1 ± 0.06	0.1 ± 0.06	0.1 (0.13)

AE: Absolute error, RMSE: Root mean square error, CE: coefficient of variation

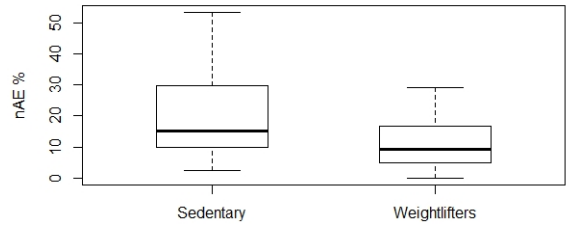

Figure 1: Boxplots displaying normalized absolute error (nAE) of key pinch force sense. Two groups are significantly different than each other, *p<0.01*

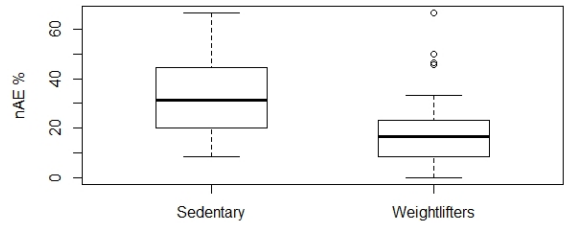

Figure 2: Boxplots displaying normalized absolute error (nAE) of tip pinch force sense. Two groups are significantly different than each other, *p<0.01*

Normalized CE, nRMSE and CV values of weightlifters were not significantly different than of sedentary, either for key or tip pinch (p>0.05).

DISCUSSION

Because the purpose of the study was to assess the effects of strength training on force sense, first we have measured maximum pinch strength values of participants in order to evaluate force sense and concluded that adolescent weightlifters have higher key and tip pinch strength compared to sedentary peers. Szlezak *et al.* had also reported similar findings in adult male weightlifters in comparison with untrained males (19). In the scientific literature, normative data for key and tip pinch strength is defined in an age and gender-specific manner, even with special regard to different levels of occupational demand, for adults and elderly as well as for children (17,20,21). Several researches have so far reported pinch strength values of rock climbers, baseball pitchers, wrestlers, handball, basketball and wheelchair basketball players (22–26). For instance, sub-elite female handball players (age 19-26) mean right key pinch strength was 18 ± 4.2 Ibs and mean right tip pinch strength was 12.5±2.0 Ibs; whereas sub-elite female basketball players of the same age had a mean right key pinch strength value of 23.4± 3.1 Ibs and a mean right tip pinch strength value of 15.3±2.2 (23). Another study reported that, elite male collegiate wrestlers' (age 20-22) mean key pinch strength was 26.24± 3.33 Ibs,

whereas tip pinch strength was 18.23± 26.58 Ibs (24). High-school (age 15-17) baseball pitchers' pinch strength values were reported as 8.8±1.5 kg for key pinch strength and 6.5 ± 1.8 kg for tip pinch strength (25). Literature on pinch strength measurements of weightlifters is still very limited. In addition to its main research purposes, this study also presents normative data of pinch strength values for female adolescent weightlifters that are significantly higher than sedentary peers.

Essentially, in this study it was aimed to investigate the long-term effects of weightlifting training on pinch force sense. Indeed, we have observed that elite adolescent weightlifters display higher accuracy in both key and tip pinch force sense compared to sedentary peers. However, long-term weightlifting training haven't improved precision in our study. Directionality of error in weightlifters', namely under-/overshooting also wasn't different than that of sedentary.

Whether exercise associated improvement in force sense originates from central or peripheral mechanisms is yet to be revealed. There are several peripheral adaptations of mechanoreceptors to training. Muscle spindle reacts to training with some microlevel metabolic changes and with a decrease in the latency of the stretch reflex response and an increase in the amplitude at a more macro level (27). It is also proposed that a disinhibition or decreasing the sensitivity of Golgi tendon organ via strength training is possible and in fact this is part of athletic training (28). On the other hand, central adaptations are also hypothesized to contribute to improvements in force sense. It can be speculated that well-known effects of training, such as alterations in corticospinal excitability and the size of motor evoked potentials may have played a part in higher accuracy observed in weightlifter group (29). Also, repeated practice of a motor skill causes plastic changes in central nervous system, in other words training can increase cortical representation of the joints resulting in improved proprioception (30).

There are several limitations of this study. One is that our participants consist of only females, which is hindering gender comparisons. The possible effects of menstrual cycle on strength were not taken into account as well. Limited number and the lack of standardization of participants according to developmental stage are other major limitations of this study.

CONCLUSION

Adolescent female weightlifters had higher tip and key pinch strength values than sedentary controls. Results of this study have also demonstrated that regular weightlifting training improves accuracy in pinch force sense, without affecting precision or directionality of error. The accuracy of force sense in adult or senior weightlifters should also be investigated with further studies.

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