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Relationship between Hand-Eye Coordination and Hand Grip Strength in Elite Taekwondo Athletes

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Abstract

Hand-Eye Coordination (HEC) and Hand Grip Strength (HGS) are among the most important skills in Taekwondo. On a technical level, HEC reflects neuromuscular coordination ability which enables quick responses, and HGS reflects muscle strength which indicates the strength and overall health of the athletes. Combined together, HEC and HGS likely allow Taekwondo athletes to perform better. The aim of this study was to identify if there is a relationship between HEC and HGS in elite Taekwondo athletes. 166 elite Taekwondo athletes (141 males, 25 females) voluntarily participated in this study and were divided into two categories: seniors (age >17 years) and juniors (age ≤17 years). HEC was assessed by hand-eye coordination manual dexterity test (Lafayette, IN, US) and HGS was measured using a hand dynamometer (Takei, Niigata, Japan). The results revealed that no significant relationship was observed between HEC and HGS ($p>0.05$) in elite Taekwondo athletes. Despite the several strength and neuromuscular adaptations acquired during Taekwondo practice, HEC and HGS are not significantly correlated, and hence there is no relationship between HEC and HGS in elite Taekwondo athletes. The results obtained may benefit Taekwondo coaches and athletes in improving their training strategies.

Keywords: *muscle force, muscle coordination, motor control, neuromuscular function*

Introduction

Taekwondo is a renowned Korean martial art involving the application of fast, powerful and complex kicks and punches with a great coordination (Kazemi et al., 2006). Being able to synchronize several extremities at the same time is one of the most important factors to succeed in Taekwondo. Multiple extremity coordination is the ability to use more than one extremity at the same time in a compatible and efficient manner. Hand-Eye Coordination (HEC) and Hand Grip Strength (HGS) are among the most important skills in this sport. On a technical level, HEC reflects neuromuscular coordination ability enabling quick and fine responses, however, HGS reflects the general muscle strength which plays a particularly role in strong punches (Chiodo et al., 2011; Kons et al., 2020; Pieter & Heijmans, 2000). Having a high level of HEC and HGS abilities might allow Taekwondo athletes to perform stronger and precisely controlled movements.

Neuromuscular coordination is an ability allowing the combination of several movements into an effective and efficient movement pattern (Dharma et al., 2020), by refining

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to the recruitment or inhibition of targeted motor units when visual accuracy is required (Khasawneh et al., 2009). In coordinative performance specifically, good timing is needed for fine neuromuscular activation (Cortis et al., 2009). HEC, a visual-motor function that facilitates the use of the hand towards a target, reflects the ability of both central and peripheral nervous systems (Wong et al., 2019). HEC is complex ability since several sensorimotor systems (e.g. visual system, vestibular system, proprioception, supraspinal, spinal cord and skeletal muscle system, etc.) work synergistically (Crawford et al., 2004) in order to perform different types of movement. HEC was found to be correlated with increasing age, suggesting that coordination decreases as an individual gets older (Getchell & Whitall, 2003).

At the same time, strength is a primary component of human motor skills and one of the most frequently trained motor abilities (Rdzanek et al., 2019). The development of muscle strength is promoted by a combination of several morphological and neural factors such as recruitment and synchronization of motor units (Suchomel et al., 2018). HGS, which involves the flexor muscles of the forearm and hand, is an important parameter to be assessed, since it is a marker of the upper-body muscular strength (Abaraogu et al., 2019). HGS plays a key role in injury prevention (Budoff, 2004) and in overall strength development (Tietjen-Smith et al., 2006). More recent evidence indicated that the HGS test is considered a simple and economic test which can give practical information about muscles, nerves, bones, and joints (Wind et al., 2010). In martial arts, HGS can be considered as an indicator to predict a better performance (Iermakov et al., 2016). Additionally, HGS has been related to body movements in Judo where a correlation was observed between HGS and balance control (Dias et al., 2011). When evaluating training programs, various studies have recommended martial arts training to enhance force and HEC (Kwok, 2012; Tsang et al., 2013; Wong et al., 2019). For instance, another study indicated that four weeks of Ving Tsun Chinese martial art training can improve elbow extensor isometric peak force and the time to reach peak force, although it did not enhance HEC in middle-aged and older adults living in the community (Fong et al., 2016). In contrast, research on basketball players has shown that trained athletes have significantly shorter reaction times in HEC tasks with a decrease of 23.3% compared to an increase of 8.1% of the control group (Tsang, 2014). However, existing studies have typically examined HEC and HGS separately, and there has been no investigation into the relationship between HEC and HGS in taekwondo athletes. Therefore, this study aims to determine if there is a correlation between HEC and HGS in elite Taekwondo athletes.

Materials and Methods

Participants

166 elite Taekwondo athletes (141 males, 25 females) voluntarily participated in this study and were divided into two categories: the juniors (aged ≤17 years; males: 15.48±1.12 and females: 15.19±1.01) and the seniors (aged >17 years; males: 23.34±5.09 and females: 20.50±1.13). The procedures were approved by the Scientific Research Ethics Committee of Al-Ahliyya Amman University (3/1-2020/2021). Prior to conducting the two non-invasive tests, the purpose of the study was explained to the participants, and following their consent, the necessary instructions were given. Participants were given instructions, such as not consuming caffeine before the test or any products considered stimulating.

Measurements

HEC measurement (reflecting neuromuscular coordination)

Neuromuscular coordination was evaluated by a hand-eye coordination manual dexterity test using Steadiness Tester (Lafayette Hole Type, Model 32011 Replacement Stylus, Model 32100; Lafayette, IN, US). This test consists of holding a metal-tipped stylus (with the dominant hand) in the middle of 9 consecutive holes becoming progressively smaller in diameter and stabilizing it in each hole for a period of 10 s while trying to avoid touching the perimeter of the holes. In fact, as the hole diameter becomes narrower, a higher coordination ability is required. The errors were detected by Silent Impulse Counter Model 58024C (Lafayette, IN, US). Each participant performed two trials using their dominant hand (preferred hand), the first one for stylus familiarization, and the second one for the assessment part. Factors affecting vision, such as lighting, were taken into account when applying the test.

HGS measurement (reflecting muscular strength)

A hand dynamometer (Takei Scientific Instruments Co., Ltd, Niigata, Japan) following the commonly accepted method was used to measure the HGS (kg). Following the recommendations of the American Society of Hand Therapy (Mgbemena et al., 2019), the grip bar was adjusted so that the second joints of the fingers were bent to grip the handle of the dynamometer. Concerning body position, the player stood up with the shoulder adducted and neutrally rotated. The elbow was straight, the forearm and wrist were in neutral positions, the arm was vertical, and the hand dynamometer was held close to the body. When ready, the athlete squeezed the dynamometer with a maximum isometric effort maintained for about 5 seconds (Franchini et al., 2018) without body movement. After the familiarization test with their dominant hand, the athletes performed a test for each hand.

Statistical analyses

Quantitative results were reported as mean ± SD and statistical significance was set at $p<0.05$. Pearson's correlation coefficient test was used for the correlations between HEC and HGS measurements. A two-way repeated measures ANOVA was used to identify HEC and HGS group differences (differences between males and females, as well as differences between juniors and seniors). All statistical analyses were performed using the software R (3.6.2) (foundation for statistical computing, Vienna, Austria).

Results

HEC measurements

The results concerning the HEC assessment according to sex and age are represented in Table 1. The coordination performance is expressed by the number of touches recorded between the stylus and the hole. Poor coordination is reflected when the number of touches increases, and a lower number of touches indicates a higher coordination (the value 0 is equivalent to absence of touches). The best coordination performance was obtained in the largest hole diameter (1.156 inch) since no touches (0.00) have been recorded by any of

the Taekwondo athletes (Table 2). In contrast, the poorest coordination obtained was for the smallest hole diameter (0.0625 inch) with an average of 24.77 touches and a maximum of 100 touches recorded (Table 2). As the hole diameter got narrower, the number of touches increased, hence an inverse relationship was observed. A significant sex effect was observed in holes 7 and 8. A significant age effect was observed in holes 7, 8 and 9.

HGS measurements

The average HGS obtained from both hands when all participants were considered was 32.19±7.95 kg (Table 1). Significant sex differences ($p<0.001$) were obtained suggesting that HGS measurements were significantly higher for men (32.51±7.65 kg), compared to women (25.70±3.47 kg). Furthermore, significant age differences ($p<0.001$) were revealed when comparing HGS measurements between juniors (29.84±6.94 kg) and seniors (37.39±6.86 kg), where seniors recorded a greater muscular strength (37.39±6.86 kg), compared to juniors (29.84±6.94 kg).

Relationship between HEC and HGS measurements

HGS of the dominant hand. The correlation analysis between HEC and HGS from the same hand used for the HEC (dominant hand) revealed no statistical significance ($p>0.05$) over any of the different holes (Table 2). This result suggests that no correlation was found between these two abilities when the HGS of the dominant hand was considered.

HGS mean of the two hands. The correlation analysis between HEC (for the dominant hand) and HGS mean of the two hands revealed no statistical significance ($p>0.05$) over any of the different holes (Table 2). This result suggests that no significant correlation was found between these two abilities when the HGS mean of the two hands was considered.

Table 1. Hand-Eye Coordination (HEC) performance as well as Hand Grip Strength (HGS) measurements according to sex and age for Taekwondo athletes.

HEC and HGS	Sex		Age		p-value	
	Males (n=141)	Females (n=25)	Juniors (n=130)	Seniors (n=36)	Sex effect	Age effect
			HEC Performance			
Hole 1 (1.156)	0.01 ± 0.08	0.00 ± 0.00	0.01 ± 0.09	0.00 ± 0.00	0.99	0.99
Hole 2 (1.125)	0.13 ± 0.76	0.00 ± 0.00	0.13 ± 0.78	0.06 ± 0.23	0.97	0.99
Hole 3 (0.500)	0.43 ± 1.36	0.00 ± 0.00	0.40 ± 1.35	0.25 ± 0.91	0.89	0.97
Hole 4 (0.312)	0.51 ± 1.27	0.44 ± 1.64	0.49 ± 1.14	0.53 ± 1.87	0.82	0.77
Hole 5 (0.187)	1.23 ± 2.87	2.12 ± 5.97	1.33 ± 3.00	1.47 ± 4.99	0.28	0.35
Hole 6 (0.109)	4.43 ± 7.50	3.12 ± 10.09	4.03 ± 6.48	4.97 ± 11.86	0.37	0.06
Hole 7 (0.093)	7.34 ± 11.26	7.44 ± 17.06	7.00 ± 10.29	8.64 ± 17.72	0.01	<0.001
Hole 8 (0.078)	13.24 ± 14.43	13.24 ± 22.96	12.81 ± 14.06	14.81 ± 21.49	<0.01	<0.001
Hole 9 (0.063)	24.87 ± 18.91	24.20 ± 25.76	23.88 ± 19.85	27.97 ± 20.52	0.48	0.02
			HGS Measurements			
HGS min	16.70	16.50	16.50	22.00	-	-
HGS max	51.15	33.10	48.65	51.15	-	-
HGS (dominant)	32.51 ± 7.65	25.70 ± 3.47	29.84 ± 6.94	37.39 ± 6.86	<0.001	<0.001

Note: Data are presented as: Hole (diameter in inch) and mean of touches ± SD. Sex effect, as well as age effects were analyzed using two-way repeated measures ANOVA. The value of 0 is equivalent to absence of touches.

Table 2. Correlation between Hand-Eye Coordination (HEC) performance and Hand Grip Strength (HGS) measurements for the Taekwondo athletes.

	Touches recorded for the Coordination Performance			Correlation with the HGS (dominant hand)		Correlation with the HGS (average of both hands)	
Hole diameter (inch)	Minimum	Maximum	Mean ± SD	r	p-value	r	p-value
Hole 1 (1.156)	0.00	0.00	0.00 ± 0.00	0.00	0.99	0.00	0.97
Hole 2 (1.125)	0.00	8.00	0.11 ± 0.70	-0.01	0.87	0.02	0.80
Hole 3 (0.500)	0.00	11.00	0.37 ± 1.27	-0.08	0.32	-0.10	0.19
Hole 4 (0.312)	0.00	8.00	0.50 ± 1.33	-0.04	0.58	0.09	0.24
Hole 5 (0.187)	0.00	28.00	1.36 ± 3.51	-0.07	0.34	-0.10	0.19
Hole 6 (0.109)	0.00	50.00	4.23 ± 7.92	-0.11	0.15	-0.15	0.05
Hole 7 (0.093)	0.00	82.00	7.36 ± 12.24	-0.08	0.28	-0.13	0.10
Hole 8 (0.078)	0.00	99.00	13.24 ± 15.91	-0.09	0.21	-0.13	0.09
Hole 9 (0.063)	0.00	100.00	24.77 ± 20.00	0.02	0.74	0.00	0.98

Note: Data are presented as: mean of touches ± SD. Correlation between HEC and HGS were evaluated using Pearson correlation analysis. r: Pearson's correlation coefficient; significance level: p-value <0.05.

Discussion

To the best of our knowledge, this is the first study evaluating the relationship between HEC and HGS in elite Taekwondo athletes. Several recent studies have focused on martial arts since many important and interesting skills are involved. Analyzing the possible presence of a relationship between HEC and HGS in Taekwondo would allow us to understand whether these two important parameters are related or not in this sport. Even though quick responses and strong kicks are essential when performing Taekwondo, the results obtained indicated that HEC and HGS were not significantly correlated. Hence, there is no relationship between HEC and HGS in elite Taekwondo athletes.

Following the HEC performance, an inverse relationship was observed in all groups (higher number of touches when the hole diameter decreases). In fact, as the hole diameter decreases, a higher coordination ability is required. However, no significant difference was highlighted between men and women nor between juniors and seniors. For the HGS measurements, significant age and sex differences were revealed, where men recorded a significantly higher HGS than women, and seniors recorded a significantly higher HGS than juniors. This is explained by the fact that men and seniors have a higher muscular strength than women and juniors respectively (Doherty, 2001). Since Taekwondo athletes have stronger punches with their dominant hand, the analysis of the correlation between HEC and HGS was first performed considering only the dominant hand. However, no significant correlation was obtained, the correlation analysis considering both hands was carried out (average of the obtained HGS), knowing both arms are used in Taekwondo. Even though both HEC and HGS are used in Taekwondo while performing/playing, the correlation analysis results revealed that HEC and HGS (for the dominant hand and for the two hands averaged) were not significantly related in elite Taekwondo athletes.

Some studies evaluated the relationship between HEC and HGS in several sports, or relationships involving HEC particularly. In concordance to our results, similar findings were observed in some studies. It was recently reported that although a significant correlation was observed between HEC and performance, no correlation was observed between HGS and HEC in adolescent tennis players (Pipal et al., 2017). Since tennis athletes use both HEC and HGS for precision and shots respectively while performing, this result is similar to our results. Additionally, badminton athletes had no better HEC than non-badminton athletes even though their performance levels were higher (Wong et al., 2019). However, in baseball, a relationship was observed between the hand-eye visual-motor reaction time and batting performance (Laby et al., 2018).

When evaluating a different coordination in Taekwondo which is the inter-joint coordination of the roundhouse kick, it was demonstrated that this coordination was advantageous in producing both fast kicking velocity and quick kicking time (Kim et al., 2011), and hence was related to those two parameters. It would then be interesting to evaluate different types of coordination in Taekwondo and hence evaluate which coordinations are the most related to HGS, which would be useful and beneficial to build specific training strategies. When comparing several skills in martial sports, it was observed that Karate athletes have a better HEC and Taekwondo athletes have a faster perceptual processing, stating that perceptual and motor performance differs between martial sports athletes according to the specific demands of the discipline (Chen et al., 2017).

The coordination is usually practiced in any type of sports. Since both HEC and HGS are important to perform in Taekwondo specifically, the study wanted to see if there is a relationship between these two parameters. The lack of a relationship between HEC and HGS obtained in elite Taekwondo athletes might be due to several reasons. One of the reasons might be that these skills do not necessarily involve a high precision and accuracy like the HEC test. Another reason might be the fatigue of the central nervous system during performance which could lead to a gradual loss of concentration (Enoka & Duchateau, 2016). In addition, peripheral fatigue induced by the large amount of sweat lost and thus the loss of metabolites (vitamins and minerals), could also explain the lack of this relationship in Taekwondo athletes (Lv, 2015). Furthermore, Taekwondo primarily relies on lower body movements rather than upper body movements, making HGS potentially less representative of the strength required for optimal performance in Taekwondo. Our study offers novel insights into the interaction between HES and HGS within Taekwondo, providing a comprehensive analysis by comparing different demographics (age, sex) and considering both dominant and non-dominant hands. This contributes valuable data to the broader understanding of physical attributes in martial arts. Despite including a large number of Taekwondo athletes, the groups were not homogeneous regarding sex (141 men and 25 women), possibly due to cultural and social factors prevalent in Arab countries (Sharara et al., 2018). Future research could explore the correlation between neuromuscular coordination and muscle strength of lower body parts, potentially revealing significant relationships relevant to Taekwondo performance. The findings of this study suggest that training programs for elite Taekwondo athletes might benefit from focusing separately on enhancing hand-eye coordination and hand grip strength, as no significant relationship between these parameters was found.

Conclusion

The main objective of this study was to identify if there is a relationship between HGS and HEC in elite Taekwondo athletes. Even though quick responses and strong kicks are essential when performing in Taekwondo, and despite the several strength and neuromuscular adaptations acquired during practice, HEC and HGS were not significantly correlated. Hence, there is no relationship between HEC and HGS in elite Taekwondo athletes. The results obtained should be taken into consideration by Taekwondo coaches and athletes when developing training strategies.

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Conflicts of interest

The authors certify that there is no conflict of interest.

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References

Abaraogu, U. O., Ezema, C. I., Ofodile, U. N., & Igwe, S. E. (2019). Association of grip strength with anthropometric measures : Height, forearm diameter, and middle finger length in young adults. *Polish Annals of Medicine*, *24*(2), 153-157. https://doi.org/10.1016/j.poamed.2016.11.008

Budoff, J. E. (2004). The prevalence of rotator cuff weakness in patients with injured hands. *The Journal of Hand Surgery*, *29*(6), 1154-1159. https://doi.org/10.1016/j.jhsa.2004.06.006

Chen, W.-Y., Wu, S. K., Song, T.-F., Chou, K.-M., Wang, K.-Y., Chang, Y.-C.,

& Goodbourn, P. T. (2017). Perceptual and Motor Performance of Combat-Sport Athletes Differs According to Specific Demands of the Discipline. *Perceptual and Motor Skills*, *124*(1), 293-313. https://doi.org/10.1177/0031512516681342

Chiodo, S., Tessitore, A., Cortis, C., Lupo, C., Ammendolia, A., Iona, T., & Capranica, L. (2011). Effects of Official Taekwondo Competitions on All-Out Performances of Elite Athletes. *The Journal of Strength & Conditioning Research*, *25*(2), 334. https://doi.org/10.1519/JSC.0b013e3182027288

Cortis, C., Tessitore, A., Perroni, F., Lupo, C., Pesce, C., Ammendolia, A., & Capranica, L. (2009). Interlimb coordination, strength, and power in soccer players across the lifespan. *Journal of Strength and Conditioning Research*, *23*(9), 2458-2466. https://doi.org/10.1519/JSC.0b013e3181bc1b39

Crawford, J. D., Medendorp, W. P., & Marotta, J. J. (2004). Spatial transformations for eye-hand coordination. *Journal of Neurophysiology*, *92*(1), 10-19. https://doi.org/10.1152/jn.00117.2004

Dharma, M. A. A., Mukaromah, S. B., & Hidayah, T. (2020). Differences of groundstroke training method and hand eye coordination on rally 3 minutes capability in Junio Tecad Pekalongan District. *Journal of Physical Education and Sports*, *9*(2), Article 2.

Dias, J. A., Külkamp, W., Wentz, M. D., Ovando, A. C., & Borges Junior, N. G. (2011). Efeito da preensão manual sobre o equilíbrio de judocas. *Motriz: Revista de Educação Física*, *17*, 244-251. https://doi.org/10.5016/1980-6574.2011v17n2p244

Doherty, T. J. (2001). The influence of aging and sex on skeletal muscle mass and strength. *Current Opinion in Clinical Nutrition and Metabolic Care*, *4*(6), 503-508. https://doi.org/10.1097/00075197-200111000-00007

Enoka, R. M., & Duchateau, J. (2016). Translating Fatigue to Human Performance. *Medicine and Science in Sports and Exercise*, *48*(11), 2228-2238. https://doi.org/10.1249/MSS.0000000000000929

Fong, S. S. M., Ng, S. S. M., Cheng, Y. T. Y., Wong, J. Y. H., Yu, E. Y. T., Chow, G. C. C., … & Chung, L. M. Y. (2016). Effects of Ving Tsun Chinese Martial Art Training on Upper Extremity Muscle Strength and Eye-Hand Coordination in Community-Dwelling Middle-Aged and Older Adults : A Pilot Study. *Evidence-based Complementary and Alternative Medicine : eCAM*, *2016*, 4013989. https://doi.org/10.1155/2016/4013989

Franchini, E., Schwartz, J., & Takito, M. Y. (2018). Maximal isometric handgrip strength : Comparison between weight categories and classificatory table for adult judo athletes. *Journal of Exercise Rehabilitation*, *14*(6), 968-973. https://doi.org/10.12965/jer.1836396.198

Getchell, N., & Whitall, J. (2003). How do children coordinate simultaneous upper and lower extremity tasks? The development of dual motor task coordination. *Journal of Experimental Child Psychology*, *85*(2), 120-140. https://doi.org/10.1016/s0022-0965(03)00059-6

Iermakov, S. S., Podrigalo, L. V., & Jagiełło, W. (2016). Hand-grip strength as an indicator for predicting the success in martial arts athletes. *Archives of Budo*, *12*(0). https://archbudo.com/view/abstracts/issue_id/11236

Kazemi, M., Waalen, J., Morgan, C., & White, A. R. (2006). A profile of olympic taekwondo competitors. *Journal of Sports Science & Medicine*, *5*(CSSI), 114-121.

Khasawneh, A. S., Mousa, A. A., & Atiyat, K. M. (2009). Evaluating neuromuscular coordination for hands among Physical Education Students. *The Shield - Research Journal of Physical Education & Sports Science*, *4*. https://sujo.usindh.edu.pk/index.php/THE-SHIELD/article/view/2710

Kim, Y. K., Kim, Y. H., & Im, S. J. (2011). Inter-joint coordination in producing kicking velocity of taekwondo kicks. *Journal of Sports Science & Medicine*, *10*(1), 31-38.

Kons, R. L., Orssatto, L. B. R., & Detanico, D. (2020). Acute performance responses during repeated matches in combat sports : A systematic review. *Journal of Science and Medicine in Sport*, *23*(5), 512-518. https://doi.org/10.1016/j.jsams.2019.12.004

Kwok, H. H. M. (2012). Discrepancies in fighting strategies between Taekwondo medalists and non-medalists. *Journal of Human Sport and Exercise*, *7*(4), 806-814. https://doi.org/10.4100/jhse.2012.74.08

Laby, D. M., Kirschen, D. G., Govindarajulu, U., & DeLand, P. (2018). The Hand-eye Coordination of Professional Baseball Players : The Relationship to Batting. *Optometry and Vision Science: Official Publication of the American Academy of Optometry*, *95*(7), 557-567. https://doi.org/10.1097/OPX.0000000000001239

Lv, Q. (2015). *Research on the physical fatigue recovery and Training Method of Taekwondo Athletes*. 192-195. https://doi.org/10.2991/isss-15.2015.48

Mgbemena, N. C., Aweto, H. A., Tella, B. A., Emeto, T. I., & Malau-Aduli, B. S. (2019). Prediction of lung function using handgrip strength in healthy young adults. *Physiological Reports*, *7*(1), e13960. https://doi.org/10.14814/phy2.13960

Pieter, W., & Heijmans, J. (2000). *Scientific coaching for olympic taekwondo*. Oxford : Meyer & Meyer Sport. http://archive.org/details/scientificcoachi0000piet

Pipal, B. P., Gaur, D. K., & Dahiya, J. (2017). Correlation between Hand Grip Strength and Hand Eye Coordination with Performance in Adolescent Tennis Players. *International Journal of Science and Research (IJSR)*, *6*(3), 640-643.

Rdzanek, J., Michalska, A., Wychowański, M., & Targosiński, P. (2019). Assessment of handgrip strength in young handball players aged 9-16. *Advances in Rehabilitation*, *33*(2), 13-19. https://doi.org/10.5114/areh.2019.85019

Sharara, E., Akik, C., Ghattas, H., & Makhlouf Obermeyer, C. (2018). Physical inactivity, gender and culture in Arab countries : A systematic assessment of the literature. *BMC Public Health*, *18*(1), 639. https://doi.org/10.1186/s12889-018-5472-z

Suchomel, T. J., Nimphius, S., Bellon, C. R., & Stone, M. H. (2018). The Importance of Muscular Strength : Training Considerations. *Sports Medicine (Auckland, N.Z.)*, *48*(4), 765-785. https://doi.org/10.1007/s40279-018-0862-z

Tietjen-Smith, T., Smith, S. W., Martin, M., Henry, R., Weeks, S., & Bryant, A. (2006). Grip Strength in Relation to Overall Strength and Functional Capacity in Very Old and Oldest Old Females. *Physical & Occupational Therapy In Geriatrics*, *24*(4), 63-78. https://doi.org/10.1080/J148v24n04_05

Tsang, W. W. N. (2014). The Effect of Vestibular Stimulation on Eye-Hand Coordination and Postural Control in Elite Basketball Players. *American Journal of Sports Science*, *2*(2), 17. https://doi.org/10.11648/j.ajss.20140202.12

Tsang, W. W. N., Kwok, J. C. Y., & Hui-Chan, C. W. Y. (2013). Effects of aging and tai chi on a finger-pointing task with a choice paradigm. *Evidence-Based Complementary and Alternative Medicine: eCAM*, *2013*, 653437. https://doi.org/10.1155/2013/653437

Wind, A. E., Takken, T., Helders, P. J. M., & Engelbert, R. H. H. (2010). Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? *European Journal of Pediatrics*, *169*(3), 281-287. https://doi.org/10.1007/s00431-009-1010-4

Wong, T. K. K., Ma, A. W. W., Liu, K. P. Y., Chung, L. M. Y., Bae, Y.-H., Fong, S. S. M., Ganesan, B., & Wang, H.-K. (2019). Balance control, agility, eye-hand coordination, and sport performance of amateur badminton players : A cross-sectional study. *Medicine*, *98*(2), e14134. https://doi.org/10.1097/MD.0000000000014134