



Research Article/Özgün Araştırma

Effects of dual- and multi-task conditions on hand grip strength

İkili ve çoklu görevlerin el kavrama kuvvetine etkileri

Erdi KAYABINAR¹ , Büşra KAYABINAR¹ , Ebrar ATAĞ¹ , Fatma MUTLUAY¹ 

¹Yalova University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, 77000, Yalova-Turkey

Atıf gösterme/Cite this article as: Kayabınar E, Kayabınar B, Atak E, Mutluay F. Effects of dual- and multi-task conditions on hand grip strength. *ADYÜ Sağlık Bilimleri Derg.* 2025;11(3):241-249. doi:10.30569.adiyamansaglik.1768761

Abstract

Aim: To evaluate changes in handgrip strength during different tasks.

Materials and Methods: A total of 125 volunteers participated. Handgrip strength was assessed using a hand dynamometer under six different conditions.

Results: Female participants showed a tendency to increase grip strength as balance difficulty increased, however, the addition of cognitive tasks led to a decrease ($p<0.05$). In male participants, no changes were observed during balance tasks ($p>0.05$), but similar to females, grip strength decreased with the addition of cognitive tasks ($p<0.05$).

Conclusion: Preventing the decrease in grip strength during cognitive tasks in both genders, and preventing the increase in grip strength during additional balance tasks in women, are considered to be effective in reducing the risk of injuries and workplace accidents.

Keywords: Hand grip strength; Dual task; Work conditions.

Öz

Amaç: Farklı görevler sırasında el kavrama kuvvetindeki değişiklikleri değerlendirmek.

Gereç ve Yöntem: Çalışmaya 125 gönüllü katıldı. El kavrama kuvveti el dinamometresi ile 6 farklı koşul altında değerlendirildi.

Bulgular: Kadın gönüllülerin motor görevler arasında denge zorluğu arttıkça kavrama kuvvetlerini artırma eğilimi gösterdikleri, bu görevlere kognitif görevler eklendiğinde ise kavrama kuvvetinin azalma eğiliminde olduğu ($p<0,05$); erkek gönüllülerde denge görevleri sırasında kavrama kuvvetinde değişiklik olmadığı ($p>0,05$) kognitif görevler eklendiğinde ise kadınlara benzer olarak kavrama kuvvetinin azaldığı ($p<0,05$) belirlendi.

Sonuç: Kognitif görevler sırasında her iki cinsiyette kavrama kuvvetinin sürdürülmesi ve kadınlarda denge düzenlerindeki ek görevlerde kavrama kuvvetini arttırmamalarının sağlanmasının yaralanma riskleri ve iş kazalarının önlenmesinde etkili olacağı düşünülmektedir.

Anahtar Kelimeler: El kavrama kuvveti; İkili görev, Çalışma koşulları.

Yazışma Adresi/Address for Correspondence: Erdi KAYABINAR, Yalova University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, 77000, Yalova -Turkey, E-mail: erdikayabinar@gmail.com

Geliş Tarihi/Received:20.08.2025 **Kabul Tarihi/Accepted:**19.11.2025

Yayın Tarihi/Published online:31.12.2025



Introduction

In daily life, it is rare for a task to be performed in isolation. Activities such as talking while walking or thinking about something while climbing stairs often involve the simultaneous execution of two tasks; this phenomenon is referred to as dual-task (DT).¹ During dual-task performance, individuals may prioritize one task over the other. This can lead to assigning different levels of priority to motor or cognitive activities, resulting in the adoption of strategies such as “posture first” or “posture second”.² If an interaction emerges between the two tasks, it suggests that both tasks are, at some point, competing for the same mental resources.³ Some recent findings suggest that simultaneous physical activities may influence cognitive task performance; however, there is no clear consensus on whether these effects are beneficial or detrimental. While some studies have demonstrated negative effects of simultaneous physical load, such as slowed reaction time or decreased movement accuracy (cognitive cost), others have reported positive effects (cognitive benefit) or mixed outcomes depending on the nature of the cognitive task.⁴⁻⁶

Using an object by generating a steady hand grip force during static or dynamic upper extremity postural control is a crucial activity of daily living.⁷ Considering the strong relationship between hand grip strength and the force-generating capacity of peripheral muscles, hand grip strength is also recognized as an indicator of force responses occurring in other extremities during task performance.⁸ In daily life, object manipulation often occurs alongside the simultaneous execution of cognitive and motor tasks. Purposeful object manipulation requires adaptation to individual goals and environmental constraints. Therefore, object manipulation cannot be considered a series of rote repetitions in which each movement is identical to the last, as both the environment and the purpose of the movement vary significantly.⁹ In this type of manual precision task, applying a steady and continuous grip force with a specific intensity appropriate to the object's weight requires the integration of perceptual feedback, grip force

production, arm coordination control, and cognitive functions such as attention and working memory.¹⁰

Globally, it is common for young individuals to enter the workforce starting around the age of 18. Among university students, especially those studying away from their families, it is frequently observed that they balance work and school in order to achieve socioeconomic independence and avoid being a burden on their families. Therefore, understanding how young people control handgrip strength in dual- and multi-task conditions, and whether there are gender differences in this control, is important for identifying the types of jobs they may be suited for and how they can prepare themselves for the positions they pursue. Many jobs require the integration of upper extremity functions while standing. In daily life, people frequently engage in multitasking activities such as holding a coffee cup or talking on the phone while standing or walking (e.g., a young person serving coffee to a customer in a café). Therefore, during object transport while walking, a predictive matching has been observed between grip force and the inertial force of the carrying hand; this indicates that the central nervous system (CNS) employs continuous grip force adjustment as a generalized strategy to maximize efficiency during object handling.¹¹ Determining how handgrip strength changes under different balance conditions is also important for preventing work-related injury risks, particularly among young individuals employed in such occupations.

Considering all this information, our study aims to determine how handgrip strength varies in young men and women during different dual- and multi-task conditions. In the existing literature, changes in handgrip strength are typically examined by adding a secondary motor or cognitive task to a single task, and these studies often involve small sample sizes. Based on this, our study aims to evaluate the different dual- and multi-task scenarios together and to establish reference values for muscle strength under these conditions in young adults.

Materials and Methods

Type of the study

The present study employed a cross-sectional design.

The sample of the study

Using the G*Power 3.1.9.7 software, a power analysis based on a previous study examining the effects of dual-task conditions on muscle strength determined that a minimum of 120 participants would be required for the study, with an alpha level of 0.05 and a statistical power of 90% (d effect size= 0.5404479).¹² To prevent a reduction in the sample size due to potential data loss, the recruitment process was concluded with the participation of 125 volunteers who met the inclusion criteria. The inclusion criteria for the study were defined as being between 18 and 25 years of age, not engaging in regular exercise, exhibiting a sedentary lifestyle according to the International Physical Activity Questionnaire (IPAQ), and having normal cognitive function. Individuals with any orthopedic, neurological, or other conditions that could affect muscle strength; those with a body mass index below 18 kg/m² or above 30 kg/m²; those unwilling to participate; or those who withdrew their consent during the study were excluded from the research. Following the study announcement, 132 volunteers applied to participate. Of these, 4 were excluded for exceeding the age limit, 2 were excluded due to experiencing hand pain, and 1 withdrew from the measurements.

Data collection tools

The physical activity levels of participants who voluntarily joined the study were first assessed with the IPAQ to determine their eligibility. Participants reported the frequency (days per week) and duration (minutes per day) of walking, moderate, and vigorous-intensity activities, as well as sitting time during the previous seven days. MET-minutes per week were calculated according to the official scoring protocol (walking = 3.3 METs, moderate = 4.0 METs, vigorous = 8.0 METs). Total physical activity was obtained by summing walking, moderate, and vigorous MET-minutes per week, and participants were categorized as having low, moderate, or high activity levels. Participants with a total

physical activity score below 600 MET-min/week were considered to exhibit a sedentary lifestyle. The Turkish validated version of the IPAQ were applied.¹³ Then, demographic characteristics such as age, height, weight, smoking, and alcohol consumption were recorded.

Handgrip strength was measured using a hand-held dynamometer in participants who met the study criteria under six different conditions. (Figure 1)

For the assessment of grip strength in each condition, Baseline BIMS Digital 5-Position Grip Dynamometer (Baseline Evaluation Instruments, USA) was used. The device, with a measurement capacity of up to 300 lbs (≈135 kg), features an adjustable five-position handle suitable for different hand sizes. The handle position was set individually to the most comfortable span, typically leaning toward lower positions in participants with smaller hand spans, in line with prior anthropometric recommendations.¹⁴ Participants were instructed to squeeze the device with their dominant hand using maximal force while keeping their arms at 90 degrees of flexion and positioned alongside the torso. The dominant hand was identified according to participants' self-reported hand preference for writing and routine daily activities. Each participant performed the procedure three times with 60-second rest intervals, and the highest value obtained, recorded in kilograms, was used for analysis before proceeding to the next condition.^{5,15,16} Each condition was administered to the participants in a randomized order.

The Stroop test was used as the cognitive task during the measurements. In this task, color-word stimuli may have either congruent or incongruent features, meaning that the semantic meaning of the word and the color of the ink may either match or differ.¹⁷ In our study, The Stroop test was administered in its standard paper-based format. A shortened version including only color-word stimuli was used, consisting of 24 items arranged in a 6×4 matrix. Each word was printed in an incongruent ink color, consisting of the words "RED," "YELLOW," "GREEN," and "BLUE" written in uppercase letters and presented in

mismatched colors. (Figure 2) Participants were instructed to name the ink color of each word as quickly and accurately as possible. These stimuli were placed 3 meters in front of the participants during the tasks, and participants were instructed to say the color of the words, not the words themselves.^{18,19} Hand grip measurements were initiated 5 seconds after the onset of Stroop task to ensure that participants were fully engaged in the

cognitive task and that early task-set initialization effects had subsided. This short delay consistent with evidence that neural engagement in response to cognitive demand stabilizes within the first few seconds, with hemodynamic responses typically peaking at approximately 5 seconds, thereby enhancing the temporal alignment between cognitive load and concurrent motor output.^{20,21}



Figure 1. Test conditions. **a:** Condition 1 (DT1): Sitting, **b:** Condition 2 (MT1): Sitting + Stroop test, **c:** Condition 3 (DT2): Standing, **d:** Condition 4 (MT2): Standing + Stroop test, **e:** Condition 5 (MT3): Standing on a BOSU **f:** Condition 6 (MT4): Standing on BOSU + Stroop test.

Data analysis

After data collection, analyses were conducted using the SPSS 29 software (IBM SPSS Inc., Chicago, IL, USA) package. The Shapiro-Wilk test was used to assess the assumption of normal distribution. Since the normality assumptions were met, repeated measures ANOVA was employed to evaluate

differences between tasks. The Bonferroni test was used to identify specific differences between measurements. To assess differences between male and female participants, the Independent Samples t-test was applied for numerical variables, while the Chi-Square test was used for categorical variables. The significance level was set at $p < 0.05$.



Figure 2. The stroop test.

Ethics committee approval

Following the approval of the Yalova University Non-Interventional Clinical Research Ethics Committee dated 25.06.2025 and numbered 2025/319, the study was conducted between June 2025 and August 2025 in the laboratories of the Faculty of Health Sciences at Yalova University, with

university students who voluntarily agreed to participate after the announcement was made. Informed consent was obtained from all participants who volunteered to take part in the study.

Results

The study was completed with a total of 125 participants. Of the volunteers, 98 (78.4%) were female and 27 (21.6%) were male. There were no significant differences between female and male participants in terms of age, dominant hand, or alcohol use ($p>0.05$). However, statistically significant differences were found in body mass index and smoking status ($p<0.05$). (Table 1 is here)

Male participants demonstrated significantly higher grip strength than female participants across all conditions ($p<0.05$). (Table 2)

Table 1. Demographic data.

		Female [n=89 (71.2%)]	Male [n=27 (21.8%)]	<i>p</i> *	Total [n=125 (100%)]
Age		20.70±1.55	21.00±1.51	0.321	20.78±1.54
Body mass index		22.81±4.31	25.37±4.32	0.003	23.55±4.45
Hand dominance	Right	81 (91.0%)	34 (94.4%)		115 (92.0%)
	Left	8 (9.0%)	2 (5.6%)		10 (8.0%)
Smoking status	Yes	14 (15.7%)	13 (36.1%)	0.017	27 (21.6%)
	No	75 (84.3%)	23 (63.9%)		98 (78.4%)
Alcohol usage	Yes	7 (7.9%)	5 (13.9%)	0.324	12 (9.6%)
	No	82 (92.1%)	31 (86.1%)		113 (90.4%)

*Independent samples t test

Table 2. Variation of hand grip strength results according to different conditions and genders.

	Sitting	Sitting + Stroop Test	Standing	Standing+ Stroop Test	Standing on a bosu	Standing on bosu ball + Stroop test	<i>p</i> *	Partial Eta Squared
Female	22.77±5.33	21.43±5.84	23.79±5.44	21.71±5.74	24.14±5.41	22.44±5.65	0.000	0.218
Male	37.62±6.67	32.35±5.43	36.91±6.01	33.45±5.68	37.29±5.93	32.99±5.73	0.000	0.413
<i>p</i> **	0.000	0.000	0.000	0.000	0.000	0.000		
Total	27.04±8.85	24.58±7.56	27.57±8.17	25.09±7.81	27.93±8.15	25.48±7.41	0.000	0.250

*Repeated measures ANOVA test, **Independent samples t test

When comparing handgrip strength across different conditions, statistically significant differences were observed both when all participants were evaluated collectively and when female and male participants were analyzed separately ($p<0.05$). (Tables 2–5 are here)

Discussion

As a result of our study evaluating how handgrip strength changes under various dual- and multi-task conditions, it was found that

handgrip strength varied in both male and female participants depending on different motor and cognitive tasks, and that the pattern of change differed between men and women. The most distinctive feature of our study is the use of multi-task setups that combine both cognitive and motor tasks, which have not been employed in previous studies in the literature.

Table 3. Variation of hand grip strength results under different conditions in all participants (post hoc)

		<i>p</i> *			<i>p</i> *			<i>p</i> *			<i>p</i> *			<i>p</i> *			
Condition 1	C2	0.000	Condition 2	C1	0.000	Condition 3	C1	1.000	Condition 4	C1	0.000	Condition 5	C1	0.078	Condition 6	C1	0.001
	C3	1.000		C3	0.000		C2	0.000		C2	0.534		C2	0.000		C2	0.001
	C4	0.000		C4	0.534		C4	0.000		C3	0.000		C3	1.000		C3	0.000
	C5	0.078		C5	0.000		C5	1.000		C5	0.000		C4	0.000		C4	0.832
	C6	0.001		C6	0.001		C6	0.000		C6	0.832		C6	0.000		C5	0.000

*Bonferroni test

Table 4. Variation of hand grip strength results under different conditions in female participants (post hoc)

		<i>p</i> *			<i>p</i> *			<i>p</i> *			<i>p</i> *			<i>p</i> *			
Condition 1	C2	0.004	Condition 2	C1	0.004	Condition 3	C1	0.004	Condition 4	C1	0.049	Condition 5	C1	0.000	Condition 6	C1	1.000
	C3	0.004		C3	0.000		C2	0.000		C2	1.000		C2	0.000		C2	0.001
	C4	0.049		C4	1.000		C4	0.000		C3	0.000		C3	1.000		C3	0.003
	C5	0.000		C5	0.000		C5	1.000		C5	0.000		C4	0.000		C4	0.023
	C6	1.000		C6	0.001		C6	0.003		C6	0.023		C6	0.000		C5	0.000

*Bonferroni test

Table 5. Variation of hand grip strength results under different conditions in male participants (post hoc)

		<i>p</i> *			<i>p</i> *			<i>p</i> *			<i>p</i> *			<i>p</i> *			
Condition 1	C2	0.000	Condition 2	C1	0.000	Condition 3	C1	1.000	Condition 4	C1	0.002	Condition 5	C1	1.000	Condition 6	C1	0.000
	C3	1.000		C3	0.000		C2	0.000		C2	1.000		C2	0.000		C2	1.000
	C4	0.002		C4	1.000		C4	0.001		C3	0.001		C3	1.000		C3	0.000
	C5	1.000		C5	0.000		C5	1.000		C5	0.000		C4	0.000		C4	1.000
	C6	0.000		C6	1.000		C6	0.000		C6	1.000		C6	0.000		C5	0.000

*Bonferroni test

In both men and women, muscle performance is largely influenced by the level of muscle strength, which serves as a key determining factor. Men generally possess greater physical strength due to having higher muscle mass compared to women. Additionally, lower testosterone production in women leads to reduced muscle volume, while the influence of estrogen contributes to a higher percentage of body fat. Due to these biological differences, women's muscle performance is considered to be lower than that of men.²² An analysis of the data obtained in our study revealed that men exhibited greater grip strength than female participants across all conditions, and this difference was not altered by varying motor or cognitive loads.

Higher levels of isometric force production have been documented to be associated with increased attentional demands and greater consistency of the force signal. This suggests a relationship between attentional mechanisms, motor organization, and isometric force production.⁵ In a study evaluating the maintenance of grip strength under different dual-task conditions, both younger and older adult groups exhibited reduced grip force and impaired stability control in both dominant and non-dominant hands when an additional task was introduced.⁷ This phenomenon may arise from the shifting of attentional resources away from grip force control toward arm movements; additionally, each task condition demands a different level of effort. Moreover, shifts in attentional focus can lead to delays in movement initiation, which in turn

may increase movement duration, trigger compensatory actions, and elevate the risk of accidents. Therefore, identifying these changes during dual- and multi-task performance is critically important. In another study involving eighteen healthy participants, two different setups were implemented. In the first condition, participants were asked to perform only the grip task without any concurrent cognitive task; in the second condition, they were instructed to perform the same motor task simultaneously with a cognitive task. During the dual-task condition, the preload phase, critical for encoding somatosensory input at initial object contact, was prolonged, while both maximum and holding-phase grip forces significantly increased.²³ A possible explanation for this increase in grip force is that participants may anticipate the interference caused by the simultaneous cognitive task and increase their safety margin, thereby attempting to reduce the risk of dropping the object due to less optimally planned and/or finely tuned grip force. This situation may lead to excessive and unnecessary force production, particularly in inexperienced or newly employed individuals, potentially increasing the risk of injuries. For example, young workers performing simple repetitive tasks, such as carrying trays, packaging items, or handling equipment in cafes, may apply greater grip forces when distracted or multitasking. This excessive effort could increase fatigue and the likelihood of minor wrist or hand injuries over time. As illustrated by the examples, the literature has not yet clearly established whether dual- or multi-tasking has enhancing or diminishing effects on primary task performance. While some studies report improvements in primary task performance, others demonstrate a decline.^{4,5,24} The data obtained in our study showed that female participants tended to increase their grip strength as balance difficulty increased across motor tasks; however, when cognitive tasks were added to these conditions, their grip strength tended to decrease. In male participants, no significant changes in grip strength were observed across different motor balance tasks, but similar to females, the addition of cognitive tasks to any condition resulted in a decrease in grip

strength. When the data of all participants were analyzed collectively, it was found that cognitive tasks led to a statistically significant reduction in grip strength, while balance-related tasks did not produce significant differences. This finding suggests that in real-life work environments, where cognitive tasks are frequently added to ongoing motor activities, a reduction in strength may occur in both genders. However, in women, the addition of balance tasks may lead to an increase in grip strength, similar to the trends observed in previous studies, potentially raising the risk of injury due to excessive force application. In the study conducted by Chen et al., it was also demonstrated that individuals exposed to a perturbation exhibited an increase in grip strength.²⁵ Bleyenheuft et al. (2009) also proposed the hypothesis that this increase in grip strength represents an anticipatory postural adjustment, based on the prediction of potential effects resulting from an impending perturbation.²⁶ The results obtained from female participants in our study were found to be consistent with this information; however, the same findings were not observed in male participants.

In a study comparing young women and men during various dual-task performances, women showed a greater decline in motor performance, particularly in muscle force and speed, while men exhibited no significant change.¹² This finding aligns with the results observed in our study regarding cognitive tasks. However, evaluating changes in grip strength not only during motor dual tasks but also under combined cognitive and motor multi-task conditions is more crucial for identifying injury risks in both women and men. Understanding the relationship between gender and dual-task performance is important for real-life multitasking activities (such as driving) that require performing several tasks simultaneously while maintaining attention.¹²

The differing effects of added cognitive and motor tasks observed in our study have also been frequently discussed in the literature. In studies examining changes in Stroop test performance during sitting, standing, and walking, some have shown that standing reduces the Stroop effect compared to

sitting^{17,27}, while others have reported no significant change.^{18,28} However, there is no comparable study in the literature that evaluates changes in primary task performance resulting from the addition of the Stroop test during multi-task conditions. In our study, the decrease in primary task performance following the inclusion of the Stroop test can be explained by a shift in task-related attention toward the cognitive task. Given the lack of evidence in the literature regarding the nature of this effect, the findings of our study are considered to contribute valuable insights to this area of research.

Limitations and Suggestions

The most significant limitation of our study is the lack of assessment of momentary fluctuations (stability) in grip strength during the different task conditions. Future studies would benefit from evaluating such fluctuations under varying motor and cognitive tasks, as well as identifying how grip strength changes throughout task execution. The unequal distribution of male and female participants is also a limitation of this study. Although the total sample size of 120 was determined based on a power analysis performed for repeated measures between tests in the total sample, this calculation was not conducted separately for sex-based subgroups. Because the number of male participants was relatively small, the results mainly reflect female participants. Therefore, between-sex comparisons may be underpowered, and the findings cannot be fully generalized. Also, this study did not include the assessment of Stroop test performance parameters. Future studies should consider including Stroop effect measures to provide a more comprehensive understanding of cognitive–motor interactions.

Conclusion

Grip strength is used constantly in daily life, and the force that can be generated varies continuously due to both environmental and internal factors. This control becomes especially important for individuals who are new to the workforce and employed in jobs requiring physical use of the hands, particularly under varying cognitive and motor loads. Based on the findings of our study,

ensuring that grip strength is maintained during cognitive tasks in both men and women—and preventing excessive increases in grip strength during additional balance tasks in women—may help reduce injury risks and workplace accidents. These insights also highlight the importance of implementing strength control training as a preventive measure before entering such occupations.

Ethics Committee Approval

This study was conducted following the approval of the Yalova University Non-Interventional Clinical Research Ethics Committee dated 25.06.2025 and numbered 2025/319.

Informed Consent

Informed consent was obtained from all participants who volunteered to take part in the study.

Author Contributions

Conceptualization: EK, BK; Design: EK, BK, EA, FM; Auditing: FM; Resources: EK, FM ; Data collection: EK, BK, EA; Data analysis and interpretation: EK, BK, EA, FM; Literature review: EK, BK, EA; Writers: EK, BK, EA; The final version of this article was read and approved by all authors.

Acknowledgments

None

Conflict of Interest

The authors declare that there is no conflict of interest for this study.

Financial Disclosure

There is no financial support for this study.

Statements

These data have not been presented or published anywhere previously.

Peer-review

Externally peer-reviewed.

References

1. Gomez-Alvaro MC, Leon-Llamas JL, Melo-Alonso M, Villafaina S, Domínguez-Muñoz FJ, Gusi N. Test–retest reliability of isokinetic strength in lower limbs under single and dual task conditions in women with fibromyalgia. *Journal of Clinical Medicine*. 2024;13(5):1288.

2. Peterson DS. Effects of gender on dual-tasking and prioritization in older adults. *Gait & Posture*. 2022;97:104-108.
3. Pashler H. Dual-task interference in simple tasks: data and theory. *Psychological bulletin*. 1994;116(2):220.
4. Park H-B, Ahn S, Zhang W. Visual search under physical effort is faster but more vulnerable to distractor interference. *Cognitive Research: Principles and Implications*. 2021;6:1-14.
5. Guzmán-González B, Bustos-Briones C, Calatayud J, et al. Effects of dual-task demands on the complexity and task performance of submaximal isometric handgrip force control. *European Journal of Applied Physiology*. 2020;120(6):1251-1261.
6. Erdogan G, Vogt L, Giesche F, et al. Cognitive costs in motor-cognitive performance assessments depend on movement complexity and cognitive task design. *Frontiers in sports and active living*. 2025;7:1482976.
7. Lin B-S, Kuo S-F, Lee I-J, et al. The impact of aging and reaching movements on grip stability control during manual precision tasks. *BMC geriatrics*. 2021;21(1):703.
8. Evyapan S, Karahan AY. El kavrama kuvveti ile periferik kas kuvveti arasındaki ilişki; Kesitsel çalışma. *Ege Tıp Bilimleri Dergisi*. 2023;6(3):60-67.
9. Grafton ST. The cognitive neuroscience of prehension: recent developments. *Experimental brain research*. 2010;204(4):475-491.
10. Huang C-Y, Cherng R-J, Hwang S. Reciprocal influences on performances of a postural-suprapostural task by manipulating the level of task-load. *Journal of Electromyography and Kinesiology*. 2010;20(3):413-419.
11. Gysin P, Kaminski TR, Gordon AM. Coordination of fingertip forces in object transport during locomotion. *Experimental brain research*. 2003;149(3):371-379.
12. Elshorbagy R, Alkhalidi H, Alshammari N, El Semaary M. Influence of sex on cognitive and motor dual-task performance among young adults: a cross-sectional study. *Annals of Rehabilitation Medicine*. 2024;48(2):163-170.
13. Sağlam M, Arikan H, Savci S, et al. International physical activity questionnaire: reliability and validity of the Turkish version. *Perceptual and motor skills*. 2010;111(1):278-284.
14. Ruiz-Ruiz J, Mesa JL, Gutiérrez A, Castillo MJ. Hand size influences optimal grip span in women but not in men. *The Journal of hand surgery*. 2002;27(5):897-901.
15. Lage V, Silva G, Lacerda A, et al. Functional tests associated with sarcopenia in moderate chronic obstructive pulmonary disease. *Expert Review of Respiratory Medicine*. 2021;15(4):569-576.
16. Herranen P, Palviainen T, Rantanen T, et al. A polygenic risk score for hand grip strength predicts muscle strength and proximal and distal functional outcomes among older women. *Medicine and Science in Sports and Exercise*. 2022;54(11):1889-1896.
17. Peskar M, Omejc N, Šömen MM, Miladinović A, Gramann K, Marusic U. Stroop in motion: Neurodynamic modulation underlying interference control while sitting, standing, and walking. *Biological psychology*. 2023;178:108543.
18. Caron EE, Reynolds MG, Ralph BC, Carriere JS, Besner D, Smilek D. Does posture influence the Stroop effect? *Psychological Science*. 2020;31(11):1452-1460.
19. Wollesen B, Voelcker-Rehage C. Differences in cognitive-motor interference in older adults while walking and performing a visual-verbal Stroop task. *Frontiers in aging neuroscience*. 2019;10:426.
20. Polimeni JR, Lewis LD. Imaging faster neural dynamics with fast fMRI: A need for updated models of the hemodynamic response. *Progress in neurobiology*. 2021;207:102174.
21. Li M, Newton AT, Anderson AW, Ding Z, Gore JC. Characterization of the hemodynamic response function in white matter tracts for event-related fMRI. *Nature communications*. 2019;10(1):1140.
22. Boisseau N. Gender differences in metabolism during exercise and recovery. Nutritional implications. *Science Et Sports*. 2004;19(5):220-227.
23. Guillery E, Mouraux A, Thonnard J-L. Cognitive-motor interference while grasping, lifting and holding objects. *PloS one*. 2013;8(11):e80125.
24. Plummer P, Eskes G. Measuring treatment effects on dual-task performance: a framework for research and clinical practice. *Frontiers in human neuroscience*. 2015;9:225.
25. Chen B, Lee Y-J, Aruin AS. Control of grip force and vertical posture while holding an object and being perturbed. *Experimental brain research*. 2016;234(11):3193-3201.
26. Bleyenheuft Y, Lefevre P, Thonnard J-L. Predictive mechanisms control grip force after impact in self-triggered perturbations. *Journal of Motor Behavior*. 2009;41(5):411-417.
27. Rosenbaum D, Mama Y, Algom D. Stand by your stroop: Standing up enhances selective attention and cognitive control. *Psychological science*. 2017;28(12):1864-1867.
28. Šömen MM, Peskar M, Wollesen B, Gramann K, Marusic U. Does standing up enhance performance on the stroop task in healthy young Adults? A systematic review and meta-analysis. *International journal of environmental research and public health*. 2023;20(3):2319.