



Influence of Sex on Cognitive and Motor Dual-Task Performance Among Young Adults: A Cross-Sectional Study

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Objective: To investigate the sex-related differences in single-task performance through motor torque, cognitive tasks and walking speed, and the combined dual-task costs (DTCs) considering both motor and cognitive performance in young adults.

Methods: Sixty-seven non-athletic subjects 37 females and 30 males were enrolled. The study measured their knee extension muscle torque using an isokinetic strength dynamometer and their walking speed using the one step app. these assessments were performed both with and without a cognitive task, and the DTCs were calculated.

Results: The females exhibited significantly larger motor performance dual task effect through (torque-DTC, speed-DTC) compared with males while exhibiting smaller cognitive dual task effect with muscle torque and speed.

Conclusion: Deterioration in motor performance during muscle force production and speed during dual tasks was large in females compared to males, whereas males experience a decline in cognitive ability when performing dual tasks compared with females.

Keywords: Dual task, Cognition, Torque, Sex

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INTRODUCTION

Humans perform everyday activities in a variety of situations while simultaneously using their motor, cognitive, and sensory functions, therefore they cannot be performed as a single task [1]. As a result, human activities consist of several tasks or dual tasks [2]. Dual tasking, or the action of managing several, concurrently tasks, is prevalent throughout daily life. In particular, the bulk of our mobility tasks (such as standing, walking, stepping, etc.) are performed while being interrupted by another motor and/or cognition task [3]. One characteristic of dual task is that performance on one or both tasks decline when carried out simultaneously [4]. These variations in performance are

known as dual task effects (DTEs), when utilizing dual task, you may prioritize one job over another. This might result in people prioritizing mobility or cognitive activities differently [5], leading to strategies called “posture first” or “posture second” in the context of mobility [3]. Cognitive functions are skills that are rooted in the brain and enable individuals to perform tasks of varying levels of complexity, which are essential in everyday life [6].

Measuring walking speed is an appropriate and reliable way to assess and monitor functional status and overall health in various populations and overall it is a sensitive measure [7] to record the level of functional status.

In both males and females, muscle performance is greatly influenced by the level of muscle strength, which is a crucial factor

[8]. Several factors play a role in determining muscle performance, including physical build, age, height, and sex [9]. Compared to females, males typically have greater physical strength, possibly due to having a higher muscle mass and lower body fat [10] in addition to females' lower testosterone production resulting in lower muscular volume, and the influence of estrogen leading to a higher percentage of fat mass, it is impossible for females to perform at the same level as their male counterparts [11].

This study aims to explore how sex impacts dual task performance by examining the cognitive and motor abilities of individual's male and female participants during a dual task paradigm (i.e., the ability to generate muscular strength and perform physical movements while engaging in a cognitive activity at the same time). Comprehending the correlation between sex and dual task performance is important for a variety of real-world activities that require multitasking, such as driving, where individuals need to be able to perform multiple tasks simultaneously while maintaining attention and focus. Research suggests that dual task performance can be improved with practice and training. However, it is important to note that there are limits to how much an individual can multitask effectively. If sex differences in dual task performance do exist, this knowledge could help inform the development of interventions or training programs that target these differences and improve overall performance. For example, some studies have found that females may perform better on dual task paradigms by combination of walking and engaging in a cognitive task simultaneously compared to males. Other studies have found there are no notable variations between sexes in dual task performance.

Elderly males exhibited greater postural instability compared to their female counterparts under dual task conditions [12]. A different research found that gait measures in older females show a greater degree of variation [13] compared with males. Falls are a significant public health concern, particularly among older adults. Prior research has indicated that dual task performance may be a predictor of fall risk in older adults. By investigating the effect of sex on dual task performance in adults, this study may provide insights into potential sex-specific fall risk factors and inform the development of targeted interventions to reduce fall risk in adults.

METHODS

Participants

During the period between July and September of 2023, a

research study was conducted involving 67 non-athlete participants, consisting of 37 females and 30 males from Jouf University students aged between 20 and 35 years. The research Ethic Committee at Qurayyat Health Affairs approved the study (No. H-13-S-071) and the ClinicalTrials was registered under ID (NCT05912530). The study had specific inclusion criteria, which included having a body mass index (BMI) between 18 and 25 kg/m², normal range of motion at the time of the test, and not taking any medications or having any health issues that could affect their physical ability. Participants with musculoskeletal injuries to the leg, cognitive impairments, history of surgery, cardiovascular conditions, or any other health issue that could impact their physical ability were excluded. The participants were given information that their involvement was optional and confidential, and they gave their consent by signing. No reward or benefit was offered for their participation.

Instrumentations

The System 4-Pro Isokinetic Strength Dynamometer (Biodex) used to measure muscle torque for the knee extension. The dynamometer is a reliable and safe method that provides valid measurements. In order to train and test various muscle groups, the use of thigh, trunk, and dorsal bands was employed to provide support for the thigh, trunk, and foot while measuring angular position, torque, and velocities [14]. The maximum force of the concentric knee extension muscles during isokinetic movement at an angular velocity of 60°/s was determined, and the peak torque (PT) was calculated by dividing the PT by the body weight (BW) ratio. Average speed was measured using the OneStep app on an iPhone 12 pro mobile during a 45 seconds walking test [15]. To assess functional mobility performance, speed and torque were measured in both single and dual-task situations, with cognitive tasks consisting of subtracting 3 from a number that has been chosen at random, repeatedly between 100 and 150 (Fig. 1).

Test procedure

An explanation was given to the participants about testing procedures before the tests were administered, the participants in the dual-task group were told to perform both tasks at the same time without giving preference to either one. Single and dual-task measurements were carried out in a random sequence to prevent any potential issues brought on by the same order of measurements. Participants completed a questionnaire that is filled out by the individual themselves about social and demo-



Fig. 1. Knee extension torque by System 4-Pro Isokinetic Strength Dynamometer (Biodex).

graphic characteristics. The assessment was conducted in both single-task and dual-task situations. In a single data collecting session, which included a 45 seconds walking test was conducted, according to the participant's velocity, single muscle torque production was done for a single motor task. PT/BW values have been recorded as measures of muscle motor performance. Single cognitive task were done through instruction to participant to count down from a random number between 100 and 150 in intervals of three for a duration of 45 seconds in a comfortably seated and quiet environment. The number of answers given and the number of correct ones were counted, and then the rate of correct responses (RCRs) per second was calculated using the formula:

$$\text{RCR} = \frac{\text{correct answers}}{\text{total time}} \times \frac{\text{total answers}}{\text{correct answers}}$$

Dual-task condition of 45 seconds walking test and cognitive task through a combination between the both activities. The speed was measured as a motor performance indicator during a dual task. On the other hand, RCR was calculated as the total number of responses and the number are used as indicators of

cognitive performance in a dual task. The same procedure was done by a combination between the motor torque and cognitive task. Following every single and dual-task situation, a break was provided, and individuals were instructed to complete each mobility task at a comfortable speed of their choosing. These three tests gave us three values for cognitive performance (single- and dual-task with walking speed, dual task with muscle torque production), two for functional performance (single and dual average speed), and two for muscle force production. These values were used to determine the motor and cognitive dual-task cost (DTC) values using the following formulas [4]:

$$\text{Average speed DTC (\%)} = \frac{(\text{dual task average speed} - \text{single task average speed})}{\text{single average speed}} \times 100$$

$$\text{Muscle force production test DTC (\%)} = \frac{(\text{dual task PT/BW} - \text{single task PT/BW})}{\text{single task PT/BW}} \times 100$$

$$\text{Cognitive} = \frac{(\text{dual task RCR} - \text{single task RCR})}{\text{single task RCR}} \times 100$$

Sample size calculation

In order to avoid type II error, the researchers calculated the sample size prior to conducting the experiment. The calculations were performed using G*Power software ver. 3.1.9.7. with $\alpha=0.05$, $\beta=0.2$, and an effect size of 0.40. The effect size for the impact of dual task on sex was determined based on previous work by Hollman et al. [12]. The required sample size was determined to be 66. To account for the drop-off, the sample size was expanded to 69 participants.

RESULTS

The IBM SPSS Statistics ver. 25 (IBM Corp.) was used to conduct the statistical analysis. Descriptive statistics, including mean, standard deviation, and frequencies, were computed. A significance level of $p<0.05$ was used to determine statistical significance.

The comparison between males and females for age and BMI was done using an independent test. The normal distribution of data was checked using the Shapiro-Wilk test, and the homogeneity between groups was tested using Levene's test for

homogeneity of variances. The effect of sex and task on cognition was investigated by mixed model ANOVA. Paired t-test was conducted for comparison of torque and speed between single and dual tasks. ANCOVA was conducted for comparison of dual task torque and speed between males and females. Unpaired t-test was conducted for comparison of DTC in muscle torque production, DTC in cognition during muscle torque production, speed-DTC and cognitive-DTC during speed measurement between males and females.

Subject characteristics

In this study, there were a total of sixty-seven participants, with thirty-seven being females and thirty being males. The subjects had an average age of 21.25 years and an average BMI of 23.99 kg/m². Table 1 provided information on the characteristics of the male and female participants. It was found that there were no significant differences in age and BMI between males and females ($p>0.05$).

Effect of sex and task on cognition

There was no significant interaction of sex and task ($F=2.17$, $p=0.12$), there was a significant main effect of task ($F=3.5$, $p=0.03$) and there was no significant main effect of sex ($F=0.01$, $p=0.91$).

There was a significant increase in cognition at single task compared with that at dual task torque in males ($p<0.05$) while there was no significant difference in females ($p>0.05$).

There was no significant difference in cognition between single and dual task speed and between dual task torque and dual task speed in males and females ($p>0.05$).

There was no significant difference in cognition at single task,

dual task torque and dual task speed between males and females ($p>0.05$; Table 2).

Effect of task on torque and speed

There was a significant decrease in torque at dual task compared with that at single task in males and females ($p<0.001$). There was a significant decrease in speed at dual task compared with that at single task in males ($p<0.05$) and females ($p<0.001$; Table 3).

Effect of sex on torque and speed at dual task

Dual task torque and speed of males and females were adjusted by the single task torque and speed to compensate for sex difference.

There was a significant decrease in torque and speed of females at dual task compared with that of males ($p<0.01$; Table 4).

Effect of sex on DTC in muscle force production, DTC in cognition during muscle force production, DTC in speed and DTC in cognition during speed measurement

There was a significant decrease in DTC in muscle force production of females compared with that of males ($p<0.01$) while there was a significant increase in DTC in cognition during muscle force production of females compared with that of males ($p<0.001$; Table 5).

There was a significant decrease in DTC in speed of females compared with that of males ($p<0.001$) while there was a significant increase in DTC in cognition during speed measurement of females compared with that of males ($p<0.001$; Table 5, Fig. 2).

Table 1. Subject characteristics

Characteristic	Male	Female	Mean difference	t-value	p-value
Age (yr)	21.60±1.92	20.97±1.25	0.63	1.61	0.11
Body mass index (kg/m ²)	24.63±4.44	23.46±3.61	1.17	1.19	0.23

Values are presented as mean±standard deviation.

Table 2. Mean cognition at single task, dual task torque and dual task speed of males and females

Cognition	Single task	Dual task (torque)	Dual task (speed)	MD (p-value)		
				Single vs. dual-task torque	Single vs. dual-task speed	Dual-task torque vs. dual-task speed
Male	0.39±0.14	0.33±0.17	0.34±0.20	0.06 (0.02)	0.05 (0.12)	-0.01 (>0.99)
Female	0.35±0.16	0.34±0.12	0.36±0.15	0.01 (>0.99)	-0.01 (>0.99)	-0.02 (>0.99)
MD	0.04	-0.01	-0.02			
p-value	0.34	0.75	0.74			

Values are presented as mean±standard deviation.
MD, mean difference.

Table 3. Mean torque and speed at single task and dual task of males and females

	Single task	Dual task	Mean difference	p-value
Torque				
Male	117.72±48.97	89.83±39.03	27.89	0.001
Female	65.59±42.94	38.75±29.13	26.84	0.001
Speed				
Male	4.22±0.78	4.02±0.75	0.20	0.02
Female	3.87±0.48	3.38±0.68	0.48	0.001

Values are presented as mean±standard deviation.

Table 4. Adjusted mean of dual torque and speed of males and females

	Male	Female	Mean difference	p-value
Torque	72.52±3.97	52.78±3.52	19.74	0.001
Speed	3.85±0.08	3.53±0.07	0.32	0.004

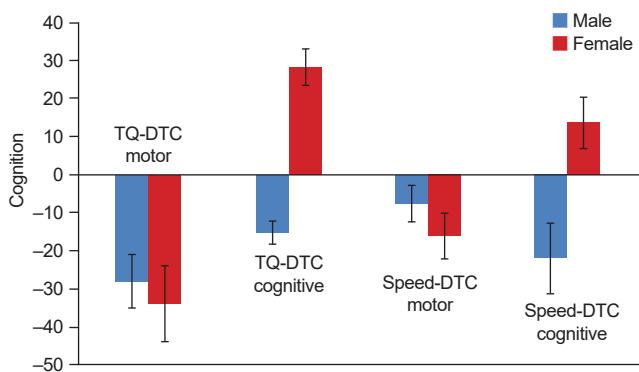
Values are presented as mean±standard error.

Table 5. Mean TQ-DTC motor, TQ-DTC cognitive, speed-DTC motor, and speed-DTC cognitive of males and females

	Male	Female	Mean difference	p-value
TQ-DTC motor	-28.06±7.12	-33.98±9.95	5.92	0.008
TQ-DTC cognitive	-15.38±3.01	28.18±4.81	-43.56	0.001
Speed-DTC motor	-7.64±4.66	-16.19±5.95	8.55	0.001
Speed-DTC cognitive	-22.01±9.37	13.82±6.79	-35.83	0.001

Values are presented as mean±standard deviation.

TQ-DTC motor, dual task cost with muscle force production; TQ-DTC cognitive, dual task cost with cognitive; speed-DTC motor, dual task cost with speed difference; speed-DTC cognitive, dual task cost with cognitive difference.

**Fig. 2.** Mean dual task cost with muscle force production (TQ-DTC motor), dual task cost with cognitive (TQ-DTC cognitive), dual task cost with speed difference (speed-DTC motor), and dual task cost with cognitive difference (speed-DTC cognitive) of males and females.

DISCUSSION

The goal of this research was to examine how sex impacts dual-task abilities in young adults, specifically in terms of motor torque, cognitive tasks, and walking speed. Additionally, the study aimed to analyze the combined impact of cognitive and motor performance on DTCs. The focus was on observing changes in dual-task performance while engaging in various cognitive tasks.

The findings of this study suggest that there are no discernible cognitive task differences between males and females during single task, dual task with torque production, and dual walking which contradict the result of Almajid and Keshner [16]. The study findings indicated significant cognitive performance differences between males and females during both sitting and Timed Up and Go Tests (TUGs). Specifically, these differences were observed in terms of the quantity of accurate answers and mistakes made during cognitive assignments. Previous research has consistently reported that females tend to outperform males in verbal fluency and memory tasks, while males tend to outperform females in mental calculation tasks [17].

According to the study results, females experienced a notable decrease in speed when performing dual tasks, while there was no significant difference in speed between males. This is consistent with the findings of Lundin-Olsson et al. [18], who found that performing a cognitive task along with a physical activity can impede motor performance and increase the falling risk but this finding contradict with the results of Almajid and Keshner [16], who observed no difference in spatiotemporal measures or DTC between healthy young females and males while performing the TUG this may be return back to the fact that all subjects participated in this study were Arabs which may have played a role in the contradiction of the results to previous studies which conducted on American females and males. It is plausible that cultural differences in gait performance should be taken into account.

The study revealed females experienced a greater decline in motor performance, specifically muscle force production and speed, during dual tasks compared to males. On the other hand, males had worse cognitive performance during dual tasks compared to females which accept the theory of Clark [19] once the demands on attention of any two activities beyond overall attention capacity, the performance on the motor task, cognitive task, or both could be impaired in comparison to single-task performance. Interestingly, new research suggests that sex may influence prioritizing during mobility tasks. For example,

Agmon et al. [20] was found that females have higher motor DTE but lower cognitive DTE than males, and that sex affects the impact of personality on DTE. However, two smaller studies showed that there was no difference in DTE for cognitive and gait tasks between sexes, although males seemed to have more variety in gait than females during dual-task walking [12].

Stoet et al. [21] conducted a study that assessed the multi-tasking ability of both males and females in a realistic setting. Their results revealed that females performed better than males in a task that measures high-level cognitive skills, including planning, monitoring, and inhibition. These findings support the idea that posture may be more important for males than females in multitasking situations.

During a cognitive activity without priority, both males and females reduced their walking speed compared to normal walking which partially contradict our result. Females are more adaptable and responsive to the task instructions, while males' gait speed is less affected. Although sex differences have been observed during other dual-task activities this study is the first to confirm sex variations in dual-task effects on gait [12].

On the other hand, these results also highlight differences in how males and females behave while using a cellphone while driving. Specifically, the study found that females had significantly longer brake response times and reduced stopping precision when distracted by their phone. However, when evaluated without the distraction, females exhibited faster brake response times and greater accuracy compared to males. This suggests that females prioritize cognition over motor performance, while males prioritize motor performance over cognition. These findings align with the "females follow the posture second theory" and the "males posture first theory" [22].

It has been shown that the difficulty to sustain a conversation during walking ("stop walking when talking") is a predictor of future falls in older individuals [23]. Recently, a greater number of researches have recently studied the dual-tasking paradigm, as the first trials undertaken provided positive findings in the dual task's capacity to be a clinical indicator of impaired cognition [24-26], fall risk [26-28] and frailty state [29,30] in elderly individuals.

de Barros et al. [31], the study conducted by the author noted that walking performance is affected by path complexity and dual-task situations. Additionally, recent studies have demonstrated that performing multiple tasks or splitting attention between tasks can lead to a decline in walking performance, even among healthy individuals [32]. This is also observed in individuals who have neurological disorders [33,34]. Earlier re-

search has demonstrated that when older individuals are tested under dual task conditions, they exhibit a decrease in their gait velocity, cadence, and stride time variability [35,36].

Deterioration in motor performance and speed during dual tasks was greater in females than in males, while males experienced a decline in cognitive ability when performing dual tasks compared to females. The study had certain limitations, including the psychological and physical condition of the patients throughout the research. Additionally, another limitation was the lack of documentation regarding the education levels and the absence of control for general cognitive ability and mobility task chosen, the speed measurement through the OneStep application has limitations. While it is easy to use and commonly employed in clinical settings, this method only offers a basic assessment of mobility speed. Conducting further evaluations of gait, which are more extensive and yield more detailed results (such as using inertial sensors), will offer more nuanced information. Second, we only assessed one secondary cognitive task. Different cognitive tasks may be differentially challenging across sexes. So authors recommend conducting a similar study with a larger and more diverse sample population that includes individuals with varying psychological and physical conditions. Additionally, the study could benefit from including measures to control for general cognitive ability and collecting more detailed information about participants' education levels. Further study needed to be done to clarify the relationship between anatomical sex differences and gait speed test, while also distinguishing between cultural and physical factors that may contribute to ethnic differences. We utilized OneStep to perform speed analysis of the participants' movements. To enhance these findings, future studies could incorporate three-dimensional motion analysis systems to examine the kinematics in greater detail. Additionally, our sample consisted solely of young, healthy Arab adults. It would be beneficial for future studies to include a more diverse range of older adults, as they are at a higher risk of falling and may exhibit different motor responses.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTION

Conceptualization: Elshorbagy R. Methodology: Elshorbagy R, Alkhalidi H, Alshammri N, El Semary M. Formal analysis: Elshorbagy R, El Semary M. Project administration: El Semary M. Writing – original draft: Alkhalidi H, Alshammri N. Writing – review and editing: Elshorbagy R, El Semary M. Approval of final manuscript: all authors.

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