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Original Article

Physiotherapy Section

Alterations in Hand-eye Coordination and Gait in Individuals with Anxiety: A Cross-sectional Study

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ABSTRACT

Introduction: The involvement of the motor system in anxiety is barely addressed and remains under-researched in cognitive theories. Understanding the link between motor impairments and anxiety symptoms can aid in creating personalised treatments for individuals with motor disorders, thereby enhancing their productivity and career prospects. The relationships between hand-eye coordination and gait, respectively with anxiety may be overlooked if the focus is limited to core diagnostic criteria. Therefore, The present study examined how anxiety influences hand-eye coordination and spatiotemporal gait parameters in individuals, highlighting these important yet often neglected aspects.

Aim: To investigate alterations in hand-eye coordination and spatiotemporal parameters of gait in individuals with anxiety.

Materials and Methods: The present cross-sectional study was conducted at the motion analysis laboratory in the Nitte Institute of Physiotherapy, Mangaluru, Karnataka, India. The individuals were screened for anxiety using the Generalised Anxiety Disorder 7 (GAD-7) and 156 participants were included based on a GAD-7 score of ≥ 8. Participants' fine and gross motor hand-eye coordination was assessed using the Scale for Handwriting Evaluation (SHE) and the Alternate-Hand Wall-Toss Test (AHWTT), respectively. A 2D gait analysis system was used to assess spatiotemporal gait parameters. The obtained data were analysed using IBM Statistical Package for the Social Sciences (SPSS) software version 29.0.10. The Pearson's correlation coefficient (r) was utilised to assess the relationship between anxiety and hand-eye coordination, as well as between anxiety and spatiotemporal gait parameters. One-way Analysis of Variance (ANOVA) compared hand-eye coordination and gait parameters across different GAD-7 levels, while Tukey's test was used for post-hoc analyses. A p-value of less than 0.05 was deemed statistically significant.

Results: The average age of the participants was 21.37±2.35 years. The study found weak negative correlations between the AHWTT score (r= -0.358, p <0.05) and the SHE score (r= -0.285, p<0.05) with the GAD-7 score, respectively, but no correlation between the GAD-7 score and gait parameters. Significant differences were found in the AHWTT score, SHE score, walking speed and stride length across anxiety levels.

Conclusion: Anxiety levels negatively correlated with hand-eye coordination, with anxious individuals exhibiting poorer performance. However, the relationship between anxiety and gait remained inconclusive.

Keywords: Anxiety levels, Gait analysis, Handwriting, Motor disorders, Spatiotemporal analysis

INTRODUCTION

The American Psychological Association has characterised the symptoms of anxiety disorders as worry, social and performance concerns, panic episodes, avoidance behaviours and physical changes such as elevated blood pressure, sweating, palpitations, giddiness and shortness of breath [1]. According to the Global Burden of Disease 2020 statistics, there are 76.2 million incident cases, which increases the prevalence to 4,802.4 cases per 100,000 population along with 44.5 million Disability-Adjusted Life Years (DALYs) lost to anxiety disorders worldwide [2].

Cognitive theories of anxiety disorders have had a significant influence in clinical psychology for several years [3]. However, the potential involvement of the gross motor system-encompassing posture, movement and coordination- in the emotional issues connected to anxiety is only minimally addressed in these models. According to the embodied perspective of theories regarding the mind-body connection in relation to emotions and cognition, the gross motor system may be crucial for understanding disordered cognitions and emotions as they manifest in depression and anxiety disorders [4].

Gait is the primary fundamental motor function through which humans move from one location to another and gait speed is an essential measure for evaluating functional status. In humans, gait maturation occurs concurrently with the development of higher-order cerebral structures and functions, such as the prefrontal cortex, basal ganglia and cerebellum. Since gait is a complex function reflective of the integrity of higher-level brain systems, any variations in gait can indicate psychiatric disorders [5].

Similarly, coordination is the ability to regulate muscular movements through the neurological system and locomotive organs. It is characterised by the precise spatial and temporal synchronisation of hand and eye movements [6]. Coordinated hand-eye coordination is necessary for many daily activities such as eating, reaching for objects, grasping, handwriting, grooming and playing sports like tennis [7].

Emotional states such as stress, anxiety, or depression can be identified through behavioural biometrics like writing and sketching [8]. Handwriting necessitates a significant degree of precision, force regulation and coordination; thus, it is plausible to anticipate that individuals with poor motor coordination may struggle with this skill [9].

Compared to other mental illnesses like depression and schizophrenia, the gait characteristics and hand-eye coordination of individuals with anxiety are seldom researched. Connections between hand-eye coordination and gait with anxiety might otherwise go unnoticed if attention is solely focused on core diagnostic criteria. Understanding the relationship between motor impairments and anxiety symptoms is crucial for developing personalised treatment strategies for individuals with motor disorders. This approach has the potential to enhance their productivity and improve career prospects, ultimately fostering better quality of life outcomes.

The study aimed to investigate changes in hand-eye coordination and spatiotemporal gait parameters in individuals with anxiety, addressing a critical gap in understanding how anxiety manifests physically. By exploring these alterations, the research seeks to highlight the need for a comprehensive approach to treating anxiety that takes into account its impact on motor skills.

MATERIALS AND METHODS

The present cross-sectional study was conducted from May 2023 to March 2024 at the Nitte Institute of Physiotherapy in Mangaluru, Karnataka, India. Ethical clearance was obtained from the Nitte Institute of Physiotherapy's Institutional Ethics Committee, Mangaluru, Karnataka, India, with reference number NIPT/IEC/Min//24/2022-2023. After receiving ethical clearance, screening for individuals with anxiety was conducted among university students using a valid questionnaire, the GAD-7 [10].

Sample size calculation: The sample size was estimated using the software G*Power 3.1.9.4, based on a study conducted by Feldman R et al., assuming a 95% confidence level, 90% power and a coefficient of determination between anxiety and gait of 0.43 [5].

Inclusion and Exclusion criteria: The study included 156 individuals aged between 18 and 26 years with a GAD-7 score of ≥ 8 [11], who had adequate proficiency in the English language for understanding and completing the research questionnaires and had normal or corrected vision. Individuals with a GAD-7 score of < 8, those with musculoskeletal disorders that caused difficulty in writing or walking, individuals with vestibular issues or dizziness, those who had difficulty comprehending the research questionnaires and individuals who faced challenges in treadmill acclimatisation were excluded from the study.

The purpose and procedure of the study were explained and informed written consent was obtained from the participants who met the inclusion criteria.

Study Procedure

Gross motor hand-eye coordination: The assessment was conducted using the AHWTT [12]. Participants stood one metre away from the wall, facing it, while holding a tennis ball. The assessor stood beside the individual with a stopwatch. Instructions were provided on how to toss the tennis ball against the wall using an underarm motion and catch it with the opposite hand. The participant then tossed the ball against the wall again with the hand that initially caught it. This process was repeated. The maximum number of repetitions completed within 30 seconds was recorded.

Fine motor hand-eye coordination: The assessment was conducted using the SHE, a performance-based evaluation tool designed to assess handwriting [13]. The SHE addresses issues related to motor execution and consists of a total of 10 tasks. Each task is evaluated using a four-point Likert scale, with a minimum score of 0 and a maximum score of 3.

Participants were seated on a bench or chair and asked to write a pangram in a notebook placed on a table, using a pen of their choice. The assessor recorded the entire writing process using a mobile camera and captured an image of the handwriting. The videos and images of the handwriting were then evaluated based on the domains of the SHE.

Spatiotemporal parameters of gait: The 2D gait analysis system was used to assess the spatiotemporal parameters of gait. Body markers were placed on specific landmarks of the lower extremities. For recording, digital Logitech® Brio 4K cameras were positioned on the anterior-posterior and both lateral sides. The treadmill was set to a normal gait speed and the participant began walking. After six minutes of acclimatisation to the treadmill, videos were recorded from each side of the participant. The spatiotemporal parameters of gait were subsequently analysed using Kinovea® (0.9.5) software.

STATISTICAL ANALYSIS

The data were analysed using IBM SPSS Statistics version 29.0.10. Descriptive statistics, including frequency, percentage and mean±Standard Deviation (SD), were used to summarise the collected data. The Pearson's correlation coefficient (r) was employed to assess the relationship between anxiety and hand-eye coordination, as well as between anxiety and spatiotemporal parameters of gait. One-way ANOVA was conducted to compare hand-eye coordination (as measured by AHWTT and SHE scores) and spatiotemporal parameters of gait across different levels of GAD-7. Post-hoc analysis using Tukey's test was performed for multiple comparisons of AHWTT scores, SHE scores, walking speed (m/s) and stride length (m) based on GAD-7 levels. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The study included a total of 156 participants, with the majority being female (81.4%) and males making up a minority (18.6%). The average age of the participants was 21.37±2.35 years. Among the participants, 42.3% exhibited a mild level of anxiety, 40.4% had a moderate level of anxiety and 17.3% experienced a severe level of anxiety, as assessed by the GAD-7 scale [Table/Fig-1].

Parameters	Frequency (n)	Percentage (%)
Age (Mean±SD) (in years)	21.37±2.35	
Gender		
Male	29	18.6
Female	127	81.4
GAD-7 levels		
Mild (8-9)	66	42.3
Moderate (10-14)	63	40.4
Severe (15-21)	27	17.3

[Table/Fig-1]: Demographic data and Population distribution based on levels of anxiety (N=156).

The descriptive statistics of the variables in the population, using mean and standard deviation is demonstrated in [Table/Fig-2]. The participants had an average anxiety score of 11.15±3.38 on the GAD-7, with a minimum value of 8 and a maximum value of 21. The average score for the gross motor hand-eye coordination assessment measure, AHWTT, was 13.46±7.85, while the average score for the fine motor hand-eye coordination assessment measure, SHE, was 18.21±2.99. The average walking speed of the participants during the gait cycle assessment was 1.11±0.04 m/s. Their average step length and stride length were reported as 0.54±0.03 m and 1.08±0.05 m, respectively. They had an average step width of 0.07±0.02 m. The average step time was 0.49±0.03 s and the average stride time was 0.98±0.05 s during the gait cycle. The participants had an average cadence of 123.49±4.93 steps/min.

The Pearson's correlation coefficient (r) was used to examine the relationship between hand-eye coordination variables and anxiety. The GAD-7 score exhibited a weak negative correlation ($r= -0.358$, $p<0.001$) with the AHWTT score and a weak negative correlation ($r= -0.285$, $p<0.001$) with the SHE score. However, there was no correlation ($p>0.001$) between the GAD-7 score and the various spatiotemporal parameters of gait [Table/Fig-3].

The one-way ANOVA was used to compare hand-eye coordination and spatiotemporal parameters of gait according to the GAD-7 levels. There was a significant statistical difference in the AHWTT score ($F= 13.20$, $p <0.001$) and the SHE score ($F= 6.47$, $p < 0.001$) among the levels of anxiety (GAD-7): mild, moderate and severe. Similarly, walking speed (m/s) and stride length (m) demonstrated statistical differences between the levels of anxiety, with $F = 3.90$ ($p <0.05$) and $F=3.12$ ($p <0.05$), respectively. However, step length (m), step width (m), step time (s), stride time (s) and cadence (steps/min) did not show significant differences between the levels of anxiety ($p > 0.05$) [Table/Fig-4].

Variables	Mean±SD
Anxiety level	
GAD-7 score	11.15±3.38
Hand-eye coordination	
AHWTT score	13.46±7.85
SHE score	18.21±2.99
Spatiotemporal parameters of gait	
Walking speed (m/s)	1.11±0.04
Step length (m)	0.54±0.03
Stride length (m)	1.08±0.05
Step width (m)	0.07±0.02
Step time (s)	0.49±0.03
Stride time (s)	0.98±0.05
Cadence (steps/min)	123.49±4.93

[Table/Fig-2]: Descriptive statistics of the variables in the study population.
(GAD-7: Generalised anxiety disorder 7; AHWTT: Alternate-hand wall-toss test; SHE: Scale for handwriting evaluation)

	GAD-7 score	
Parameters	**r value**	**p-value**
Hand-eye coordination		
AHWTT score	-0.358	<0.001*
SHE score	-0.285	<0.001*
Spatiotemporal parameters of gait		
Walking speed (m/s)	-0.031	0.704
Step length (m)	-0.078	0.335
Stride length (m)	-0.086	0.288
Step width (m)	0.096	0.234
Step time (s)	-0.018	0.827
Stride time (s)	-0.026	0.744
Cadence (steps/min)	0.059	0.467

[Table/Fig-3]: Correlation between anxiety and hand-eye coordination scores and spatiotemporal parameters of gait, respectively.
(r: Pearson's correlation coefficient; *Significant, p-value <0.05, GAD-7: Generalised anxiety disorder 7; AHWTT: Alternate-hand wall-toss test; SHE: Scale for handwriting evaluation)

Parameters	Levels of anxiety (GAD-7 score)	Mean	SD	"F"	p-value
AHWTT score	Mild (8-9)	16.18	7.99	13.20	<0.001*
	Moderate (10-14)	13.10	6.86		
	Severe (15-21)	7.67	6.40		
SHE score	Mild (8-9)	18.89	2.81	6.47	0.002*
	Moderate (10-14)	18.21	2.99		
	Severe (15-21)	16.52	2.86		
Walking speed (m/s)	Mild (8-9)	1.11	0.04	3.90	0.022*
	Moderate (10-14)	1.10	0.04		
	Severe (15-21)	1.12	0.05		
Step length (m)	Mild (8-9)	0.55	0.03	2.51	0.085
	Moderate (10-14)	0.53	0.03		
	Severe (15-21)	0.54	0.03		
Stride length (m)	Mild (8-9)	1.09	0.05	3.12	0.047*
	Moderate (10-14)	1.06	0.05		
	Severe (15-21)	1.07	0.06		
Step width (m)	Mild (8-9)	0.07	0.02	0.35	0.707
	Moderate (10-14)	0.07	0.02		
	Severe (15-21)	0.07	0.02		
Step time (s)	Mild (8-9)	0.50	0.03	2.11	0.125
	Moderate (10-14)	0.49	0.03		
	Severe (15-21)	0.50	0.02		
Stride time (s)	Mild (8-9)	0.99	0.04	2.99	0.053
	Moderate (10-14)	0.97	0.05		
	Severe (15-21)	0.98	0.04		
Cadence (steps/min)	Mild (8-9)	122.77	4.48	1.48	0.231
	Moderate (10-14)	123.76	5.18		
	Severe (15-21)	124.59	5.31		

[Table/Fig-4]: Comparison of hand-eye coordination and spatiotemporal parameters of gait among levels of anxiety.
(F: One-way ANOVA; *: Significant, p-value <0.05, GAD-7: Generalised anxiety disorder 7, AHWTT: Alternate-hand wall-toss test; SHE: Scale for Handwriting Evaluation)

Post-hoc analysis using the Tukey's test was conducted for multiple comparisons of the AHWTT Score, SHE Score, walking speed (m/s) and stride length (m) according to GAD-7 levels. The AHWTT Score was found to be statistically different between the GAD-7 levels: mild and moderate ($p < 0.05$), mild and severe ($p < 0.001$), as well as moderate and severe ($p < 0.05$). The SHE score exhibited a significant difference between the GAD-7 levels of mild and severe ($p < 0.05$) and moderate and severe ($p < 0.05$). Additionally, walking speed and stride length were found to differ between the mild and moderate GAD-7 levels ($p < 0.05$) [Table/Fig-5].

Multiple comparisons			Mean difference	p-value
AHWTT score	Mild (8-9)	Moderate (10-14)	3.09	0.046*
		Severe (15-21)	8.52	<0.001*
	Moderate (10-14)	Severe (15-21)	5.43	0.004*
SHE score	Mild (8-9)	Moderate (10-14)	0.69	0.370
		Severe (15-21)	2.38	0.001*
	Moderate (10-14)	Severe (15-21)	1.69	0.032*
Walking speed (m/s)	Mild (8-9)	Moderate (10-14)	0.02	0.049*
		Severe (15-21)	-0.01	0.864
	Moderate (10-14)	Severe (15-21)	-0.02	0.057
Stride length (m)	Mild (8-9)	Moderate (10-14)	0.02	0.039*
		Severe (15-21)	0.02	0.417
	Moderate (10-14)	Severe (15-21)	-0.01	0.801

[Table/Fig-5]: Multiple comparisons of AHWTT score, SHE score, walking speed (m/s) and stride length (m) according to the GAD-7 levels.
(*: Significant; p-value <0.05; AHWTT: Alternate-hand wall-toss test; SHE: Scale for handwriting evaluation)

DISCUSSION

The present study enhances the authors understanding of variations in hand-eye coordination and spatiotemporal aspects of gait among individuals with anxiety. Additionally, it analyses disparities in these domains across different levels of anxiety.

The research on anxiety-induced changes to motor function is conspicuously lacking. Few investigations in the past have associated anxiety issues with decreased muscular strength, unstable posture and impaired balance [5,14].

Anxiety and gross motor hand-eye coordination: Hand-eye coordination is a pivotal aspect of carrying out daily activities and complex tasks efficiently in humans. Participants in the present study exhibited reduced gross motor hand-eye coordination performance, as evidenced by lower scores in the AHWTT and SHE. These findings are consistent with the study by Chitra D et al., which reported significant impairment in hand-eye coordination during the Jenga game among the anxious nursing population [15]. Similarly, a study on archery athletes by Arifin A et al., found a significant influence of anxiety on archery performance scores, yielding results that align with the current study [16].

The AHWTT presented a time-constrained challenge, requiring participants to complete as many tosses as possible within a set timeframe. The prospect of achieving better performance within the allotted time was perceived as a potential trigger for anxiety. It

is plausible to hypothesise that the negative correlation observed between anxiety and hand-eye coordination in this study may stem from increased activation of the amygdala due to anxiety, coupled with decreased prefrontal control, which led to challenges in task performance [15].

Furthermore, the AHWTT required individuals to aim, fix their gaze on the target and respond accordingly. Anxiety is known to significantly reduce gaze stability on visual targets [17]. Thus, anxiety-induced diversion of gaze from task performance could have plausibly contributed to the reduced scores in executive functioning observed in the present study.

Anxiety and fine motor hand-eye coordination: The current study investigated the handwriting of individuals with anxiety and established a weak negative correlation between the two. This finding suggests that anxiety may impair fine motor coordination activities like handwriting, which is consistent with the study by Mashio Y and Kawaguchi H, [18]. The study aimed to evaluate the incidence of mental health decline by investigating the relationship between mental health status and handwriting duration. Their findings revealed that individuals in the high-risk group tended to write faster in terms of handwriting speed but slower in executing the writing movement after cognitive processing compared to those in the low-risk group.

In the present study, it was observed that anxious individuals tended to support their bodies on the desk and adopted a forward-leaning posture while writing. Another significant observation was that the participants in the current study applied excessive pressure on the paper, extending up to multiple pages. The back side of the paper had a noticeably rough texture and word impressions were distinctly visible. This finding is consistent with observations reported in the study by Vyawahare N and Ashtaputre A, where participants who exhibited high levels of both stress and anxiety exerted significant pressure with their pens on the paper while writing their essays [8].

Prior research has primarily aimed to elucidate the connection between anxiety and performance by employing the Attentional Control Theory (ACT) [19]. According to this theory, anxiety is believed to impede an individual's capacity to resist interference from irrelevant stimuli during tasks. This, in turn, leads to an imbalance in the attentional systems geared towards achieving goals, ultimately diminishing task efficiency. In accordance with the ACT, increasing cognitive effort to meet task requirements correlates with a decrease in processing efficiency [20]. This concept could be relevant to the present study's findings, as it helps to justify the variation or decline in motor performance observed with increasing levels of anxiety, particularly evident between mild and severe levels. This trend was noted across both gross and fine motor coordination activities, leading to lower performance scores.

Anxiety and gait: The current study discovered a negligible correlation between gait and anxiety levels among participants. This finding aligns with the conclusion drawn in the review conducted by Feldman R et al., where gait parameters in relation to anxiety were deemed relatively insignificant [4,14]. Previous research investigating gait alterations in individuals with anxiety has indicated slower walking speed, shorter step length and reduced cadence, alongside balance deficits and impaired mobility when compared to control groups [5]. Current study data suggest that, despite the variability in anxiety levels, particularly regarding walking speed and stride length, there was inconclusive evidence to establish a correlation between anxiety and gait parameters.

Unlike the findings of the current study, participants in the research by Attwood A et al., reported slower walking and greater caution when navigating obstacles in an anxious state [21]. The majority of studies that have investigated movement changes in individuals with anxiety have introduced stressors to the participants and the environment or induced other phobias [22,23]. In contrast, the present research evaluated the spatial and temporal aspects of gait according to conventional biomechanical considerations and the fundamental theories of gait assessment. There were no immediate stressors or external factors that induced anxiety in real-time. However, factors such as the confined setup of the gait laboratory and walking on a treadmill with a moving platform during testing could be considered. Many participants noted that it was their first time using a treadmill.

Treadmill acclimatisation: Treadmill acclimatisation could potentially account for the lack of significant correlation between anxiety levels and gait in the present study. It was considered a safety measure to prevent falls during the assessment. In the current study, participants walked on the treadmill for approximately 8 to 10 minutes in total, with motion capture of gait commencing after the 6-minute mark. This protocol was implemented based on the research findings of Meyer C et al., which indicated that a minimum of six minutes of treadmill acclimatisation was necessary to achieve stable performance for inexperienced treadmill users [24]. As participants were given time to familiarise themselves with and adjust to treadmill walking, any potential anxiety triggers would likely have diminished, resulting in a more relaxed and calm state.

Limitation(s)

The present study employs a strong methodological approach, including detailed descriptions of data collection procedures, validated outcome measures and data analysis techniques. This ensures transparency and replicability, enhancing the study's credibility. However, the study has a few limitations. Firstly, a more balanced gender representation would have provided a clearer understanding of how anxiety impacts motor function across different demographics. Additionally, confounding variables, such as participants' prior experiences and motor skill proficiency, may have influenced the results despite efforts to control the testing environment. The absence of real-time stressors during testing may also have affected the observed relationship between anxiety and gait parameters.

CONCLUSION(S)

The present study contributes to the exploration of the underexplored relationship between anxiety and motor function. The study demonstrates that elevated levels of anxiety are associated with decreased manual coordination performance, as the results reveal a negative correlation that aligns with prior population-based studies. Furthermore, it addresses the relationship between the spatiotemporal parameters of gait and anxiety, revealing a negligible connection between the two in the absence of real-time stressors. These findings provide a deeper understanding of the complex relationship between anxiety and motor performance, highlighting potential avenues for future research and interventions to enhance physical and mental well-being.

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