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Original Research

Developmental coordination disorder and executive function deficits: Implications for emotional, mental, and overall well-being

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ABSTRACT

Background: Developmental coordination disorder (DCD) has been found to be associated with executive function (EF) deficits, and to negatively impact emotional (self-esteem, self-efficacy), mental, and overall well-being. Previous research has largely focused on EF deficits in children with DCD, with limited examination of adults, particularly in relation to the effect of co-occurring EF deficits on various well-being aspects.
Objectives: To investigate (1) the frequency of EF deficits in adults with DCD, and (2) whether the co-occurrence of DCD and EF deficits contributes to emotional, mental, and overall well-being.
Methods: Fifty-five adults with DCD, without hyperactive attention deficit disorder (mean age = 27.57 years, 49.1 % male), underwent a test battery to assess fulfillment of the DSM-5 criteria for DCD. They completed norm-referenced measures of everyday EF-related difficulties, as well as self-report questionnaires measuring emotional, mental, and overall well-being.
Results: Almost 50 % of the adults with DCD exhibited EF deficits, manifested mostly by 'cold' (non-emotion-related) difficulties in task monitoring, planning, and organizing, and working memory. Compared to participants with DCD alone, participants with co-occurring DCD and EF deficits had significantly ($p < 0.05$) lower emotional, mental, and overall well-being, manifested by lower self-esteem, general self-efficacy, and life satisfaction and higher psychological distress.
Conclusions: EF deficits, particularly in 'cold' domains, are highly prevalent among individuals with DCD, substantially affecting their emotional, mental, and overall well-being. The results highlight the need for a comprehensive evaluation of EF by healthcare professionals to ensure interventions address both motor and potential cognitive challenges, supporting improved well-being.

Introduction

Developmental Coordination Disorder (DCD), a neurodevelopmental disorder[1] prevalent among 7 % of adults,[2] is characterized by a core deficit in motor coordination that interferes with daily performance.[1] The impact of DCD extends beyond motor difficulties, often leading to secondary effects on various well-being aspects. This includes *emotional well-being*, particularly diminished self-efficacy and self-esteem[3,4] and *mental well-being*, including elevated levels of stress and anxiety symptoms.[3,5,6] When DCD persists into adulthood, these adverse consequences may intensify, further affecting individuals' *overall well-being*,[7] often operationalized as satisfaction with life.[8]

Individuals with DCD often have reduced executive function (EF), a set of abilities that act to initiate, maintain, and coordinate lower-level cognitive processes and to foster goal-directed behaviors.[9] Traditionally viewed as comprising working memory, inhibition, and shifting,[10] EF is now understood to also include planning, organizing, self-monitoring, and emotional-control. These components can be categorized into "cold" EF (e.g., working memory, planning), and "hot" EF, which is influenced by emotions and motivation (e.g., emotional control, self-monitoring).[11]

Research has predominantly focused on "cold" EF in DCD, while "hot" EF has received less attention. Recent reviews by Subara-Zukic et al.[12] and Lachambre et al.[13] on individuals with DCD, indicated an impairment in cold EF, with strong effects observed for inhibitory control, working memory, executive attention, and planning, as examined by computer- and performance-based measurements in a lab setting. The EF difficulties are also evident in everyday life situations, such as

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challenges with time management, organization of equipment, initiation of daily tasks, and goal setting.[14,15] However, recent research has revealed a less consistent pattern of EF difficulties among adults with DCD, showing intact inhibitory control in the stop-signal task.[16,17] Moreover, only half of a sample of children with DCD[18] and approximately one-quarter of a sample of adults[19] exhibited EF deficit. The few findings on "hot" EF in DCD are mixed. Some studies reported decreased inhibitory control in the presence of emotionally charged stimuli, using computer-based measure.[20,21] However, others found no significant effect of DCD on inhibitory control in the presence of immediate rewards or emotionally charged situations using performance-based EF measure[22,23] or on "hot" EF in everyday life situations.[5]

A recent line of work emphasizes the importance of EF for various aspects of well-being.[23,24] Specifically in DCD, everyday life EF difficulties mediate the relationship between DCD and mental well-being, i.e., anxiety and depressive symptoms.[5,25] Yet, the effect of EF difficulties on emotional and overall well-being have not been studied in DCD. Therefore, this study aims were to describe the frequency of everyday EF-related deficits in adults with DCD, including the "hot" and "cold" domains, and to compare adults with DCD, with and without EF deficit, in terms of their emotional well-being (self-esteem, general self-efficacy), mental well-being (psychological distress), and overall well-being (life satisfaction).

Methods

This cross-sectional study constitutes a secondary analysis of previously collected data from a recently completed study by Zaguri-Vittenberg et al.,[26] which examined health outcomes of adults with DCD. This study was approved by the Hebrew University Ethics Committee (28,022,022).

Participants

Participants included 55 adults with DCD aged 21–35, with a mean age of 27.57 (3.62) (49.1 % man, 50.9 % women) who were recruited using convenient sampling via social media. The sample size was calculated using G-power software and is based on expected effects given previous study that compared individuals with DCD and those with DCD and co-occurring attention deficits hyperactive disorder (ADHD) in terms of moods and emotions affecting one's well-being.[27] With an expectation of 95 % power and type-I error of 0.05, it was estimated that a sample of 54 would be sufficient to detect a large effect size.

The socio-demographic characteristics of the study sample are presented elsewhere.[26] The participants were included if they met the criteria of the Diagnostic and Statistical Manual of Mental Disorders, 5th edition - Text Revision (DSM-5-TR)[1]: (a) scored below the 5th percentile on the Movement Assessment Battery for Children - second Edition (MABC-2;)[28] and (b) scored below the 15th percentile on The Adolescents and Adults Coordination Questionnaire (AAC-Q).[29] Participants who reported having a psychiatric diagnosis, neurological deficits, or neurodevelopmental or intellectual disabilities were excluded. Participants with self-reported diagnosis of ADHD, or ADHD symptoms evaluated by means of the Adult ADHD Self-Report Scale (ASRS),[30] were excluded.

Measurements

Motor competence and attention deficits

The M-ABC-2[28] was used to measure fine and gross motor skills in three domains: Manual skills, Ball skills, and Static and dynamic balance. The standard scores for each domain are summarized, with lower scores indicating greater motor difficulty. The standard scores are converted to percentiles (0–5 % - significant motor difficulties; 5–15 % - at risk of motor difficulties; 15–99.9 % - without motor difficulties). The M-ABC-2 is considered a golden standard for diagnosing DCD in individuals up to age 16 years and 11 months, yet it is widely accepted for use in adults over 21.[16,17,31] In the current study, norms for ages 16 years to 16 years and 11 months were used, and the interpretation in classifying scores by level of motor difficulty was applied with caution (i.e., the 5th percentile was used as the inclusion criterion, see Participants section).

The AAC-Q[29] was used to measure motor coordination difficulties reflected in everyday functioning. The 12 items of the AAC-Q are rated on a 5-point scale (5 = "always experience difficulty" to 1 = "never experience difficulty"), yielding scores ranging from 12 to 60. Cut-off scores of 26–30 (represent the 5th to 15th percentile) indicate borderline DCD and scores of 31 or above (representing a score below the 5th percentile) indicate probable DCD.

The ASRS[30] questionnaire was used to evaluate the frequency of ADHD symptoms. The 18 items of the ASRS are rated on a 5-point scale (0 = *never* to 4 = *very often*), yielding scores ranging from 0–72. A screening score comprised of the sum of all items ($\geq$ 51) is predictive of symptoms consistent with ADHD.

Executive function

The Behavior Rating Inventory of Executive Function–Adult Version (BRIEF-A)[11] is a standardized self-report questionnaire for adults that measures EF-related difficulties in everyday life. It consists of 75 items rated on a 3-point scale (3 = *often experience difficulty* to 1 = *never*). These items encompass nine scales, which measure various EF domains, and are grouped into two composites: (1) the Behavioral Regulation Index (BRI) – comprising the subscales: Inhibition, Shifting, Self-Monitoring, and Emotional-Control; and (2) the Metacognition Index (MI) – comprising the subscales: Initiation, Working Memory, Planning and Organizing, Task-Monitoring, and Organization of Materials. For this study, hot EFs were operationalized by the BRI, while cold EFs were operationalized by the MI.[32] T-scores were calculated for each subscale and for the BRI and MI composites according to age, with higher scores indicating greater impairment. A score $\geq$ 65 represents EF deficits. In this study, participants were assigned to the group of adults with DCD and co-occurring EF deficits if they had a score indicating deficits in either the BRI or the MI composites.

Emotional well-being

The Rosenberg Self-Esteem Scale (RSES)[34] is a standardized self-report questionnaire for adolescents and adults that was used to measure global self-worth based on one's feelings about themselves. The 10 items are rated on a 4-point scale (1 = *strongly disagree* to 4 = *strongly agree*), yielding a total score ranging from 10 to 40 with higher scores indicating higher self-esteem.

The New General Self-Efficacy Scale (NGSE)[35] is a standardized self-report questionnaire for adults that was used to assess general self-efficacy. The eight items of the NGSE are rated on a 5-point scale (1 = *strongly disagree* to 5 = *strongly agree*), yielding a total score ranging from 8 to 40, with higher scores indicating higher general self-efficacy.

Mental well-being

The Kessler Psychological Distress Scale (K-6)[33] is a standardized self-report questionnaire for adults that was used to measure psychological distress based on the frequency of experiencing feeling nervous, hopeless, restless, or worthless. The 6 items of the K-6 are rated on a 5-point scale (0 = *none of the time* to 4 = *all the time*), yielding a total score ranging from 0 to 24 with higher scores indicating greater psychological distress.

Overall well-being

The Satisfaction with Life Scale (SWLS)[8] is a standardized self-report questionnaire for adults, that was used to measure overall well-being through life satisfaction judgments. The 5 items of the SWLS are rated on a 7-point scale (1 = *Do not agree at all* to 7 = *completely agree*), yielding a total score ranging from 5 to 35, with higher scores indicating higher overall well-being.

Procedure

Interested participants contacted the first author, signed a written consent and completed the AAC-Q and ASRS on-line. Next, the first author administered the M-ABC-2 to the participants who scored above the cut-off for DCD according to the AAC-Q and below the cut-off for ADHD according to the ASRS. Participants who met all the study's criteria completed the other study questionnaires on-line.

Data analyses

IBM SPSS Statistics version 28 was used for data analyses. Descriptive statistics was employed to describe the frequency of EF deficits according to the subscales and composites of the BRIEF-A. To examine potential confounding variables, preliminary analyses were conducted to assess differences in sex, age, and severity of motor deficits between participant with DCD with and without EF deficits, using a chi-square test and independent samples *t*-tests. Prior to conducting univariate analyses of variance (ANOVA) to examine the group differences, the normality of residuals was verified using the Shapiro–Wilk test, and the homogeneity of variances was verified using Levene's test. Subsequently, ANOVA tests were used to examine the difference between participants with DCD with and without EF deficits in relation to overall, mental, and emotional well-being aspects (SWLS, K-6, RSES, and NGES scores), and the p-values were adjusted by Bonferroni correction. The significance level was set at $p < 0.05$.

Results

Everyday executive function-related difficulties

Of the 55 adults with DCD, 27 (49.1 %) were found to have co-occurring EF deficits (based on the BRIEF-A's BRI or MI $\geq$ 65), of whom, 6 (10.9 %) had a deficit in hot functions as measured by the BRI composite (*Mean* = 53.73 (9.77), *Range* = 37–72), 16 (29.1 %) had a deficit in cold functions as measured by the MI composite (*Mean* = 61.31 (11.47), *Range* = 36–87), and 5 (9.1 %) had a mixed pattern deficit in both BRI and MI composites. When further examining the proportion of deficits in each sub-domain (BRIEF-A subscales, Table 1), the results yielded a higher frequency of deficits in cold EF sub-domains. In contrast, within the hot EF composite, a relatively high rate of deficits was observed only in Shifting. Finally, 41 (74.5 %) of the participants demonstrated a deficit in one or more of the BRIEF-A subscales, although only part of them demonstrated global hot or cold deficit according to the BRI or MI composite.

Table 1
Scores on the BRIEF-A's subscales and the percent of participants found to have deficits in the subscales ($n = 55$).

	t-score		Deficit[a]
BRIEF-A Subscale	*Mean (SD)*	*Range*	n (%)
Hot EF			
Inhibition	52.47 (9.29)	36–77	4 (7.3)
Shifting	59.96 (11.52)	39–83	20 (36.4)
Emotional control	51.93 (11.44)	38–80	9 (16.4)
Self-monitoring	47.98 (9.78)	37–68	3 (5.5)
Cold EF			
Initiation	57.71 (11.34)	37–82	17 (30.9)
Working memory	60.96 (11.44)	39–88	21 (38.2)
Planning and organizing	59.02 (11.29)	38–84	20 (36.4)
Task monitoring	61.13 (11.91)	36–88	23 (41.8)
Organization of materials	59.73 (12.94)	36–81	19 (34.5)

Note. a - EF deficit – according to a subscale score $\geq$ 65. BRIEF-A, Behavior Rating Inventory of Executive Function–Adult Version; EF, executive function.

Group differences in overall, mental, and emotional well-being

First, to detect a possible confounding effect of age, sex, and severity of motor deficit, group differences were examined regarding these characteristics. No differences were found for age ($p = .71$) and sex ($p = .14$); participants having only DCD (age: *Mean* = 27.39 (3.34); 39.29 % man) demonstrated a similar age and sex distribution compared to participants with co-occurring DCD and EF deficits (age: *Mean* = 27.75 (3.95); 59.26 % man). Yet, there were significant ($p < .05$) group differences in the severity of motor deficits (i.e., M-ABC-2 total standard score), with participants having co-occurring DCD and EF deficit, $M = 4.22$ (0.89), demonstrating a higher motor deficit severity compared to participants with only DCD, $M = 4.71$ (0.53).

Next, we examined the correlation between the severity of motor deficit and the emotional, mental, and overall well-being aspects. The results yielded low and non-significant ($p > .05$) correlations with each of the variables (RSES: $r = 0.26$; NGES: $r = 0.18$; K-6: $r = -0.17$; SWLS: $r = 0.16$). Therefore, in the subsequent analyses, age, sex, and severity of motor deficit were not considered confounding variables. In comparing participants with only DCD to those with co-occurring DCD and EF deficit, as expected, the univariate tests showed that participants with co-occurring DCD and EF deficit reported significantly lower emotional, mental, and overall emotional well-being compared to participants with only DCD (Table 2).

Discussion

Executive function (EF) deficits are commonly associated with DCD. However, most prior research has focused on children with DCD and emphasized "cold" EF, with limited attention to "hot," emotion-related EF domains. Additionally, there is a gap of knowledge about the impact of co-occurring EF deficits on various aspects of well-being. This study investigated the proportion of everyday EF-related deficits within a sample of adults with DCD, examining both hot and cold EF domains. Additionally, it explored the impact of co-occurring EF deficits on

Table 2
Mean scores (SD) and differences between study groups in emotional, mental, and overall well-being ($n = 55$).

		DCD only $n = 28$	DCD and co-occurring EF deficit[a] $n = 27$		
	Mean (SD)	*Mean (SD)*	*F*	*F*	η^2_p
Emotional well-being					
Self-esteem (RSES)	31.54 (4.57)	28.59 (4.70)	5.55	5.55	.095
General self-efficacy (NGSE)	30.86 (4.62)	27.59 (6.02)	5.12	5.12	.088
Mental well-being (K-6)	4.89 (2.69)	8.48 (3.58)	17.79	17.79	.251
Overall well-being (SWLS)	25.14 (5.18)	21.89 (4.93)	5.69	5.69	.097

DCD, developmental coordination disorder; EF, executive function; SWLS, Satisfaction with Life Scale; K-6, The Kessler Psychological Distress Scale; RSES, Rosenberg Self-Esteem Scale; NGSE, New Global Self-Efficacy Scale.
a - EF deficits – according to a score $\geq$ 65 in the BRI, the MI, or both composites.
b - Adjusted by Bonferroni correction.

various aspects of well-being, by comparing outcomes between adults with DCD, and those with co-occurring DCD and EF deficits.

EF deficits in adults with DCD

The results indicated a frequency of almost 50 % of EF deficits within the sample of adults with DCD. A noteworthy finding is that three-quarters of the participants displayed deficits in specific EF sub-domains, yet not all met the threshold for an overall EF deficit. This highlights that EF deficits in DCD are not uniform, as individuals may exhibit challenges in selected domains that do not necessarily constitute a global impairment.[16,29] By excluding adults with DCD with co-occurring ADHD, contrary to previous studies on the topic,[13–15,29,38] this study provides a unique insight into the frequency of EF deficits in DCD that are not explained by ADHD symptoms.[27,36]

As far as we know, only few studies have examined the proportion of EF deficits in a group of individuals with DCD. Similar to our findings, Wilson et al.[18] reported a 50 % proportion of cold EF deficits in a sample of children with DCD. In contrast, among adults with DCD, Broletti et al.[5] reported a proportion of 77.3 % for EF deficits, while Järvinen et al.[19] reported a proportion of 27.8 %. It is possible that the results regarding EF in DCD varied due to methodological differences between studies.[37] For instance, Broletti et al.'s[5] sample included individuals with probable DCD (rather than confirmed per DSM-5 criteria), and common comorbidities which may influence EF. Moreover, the current study operationalized EF deficits as a score above the cutoff in either the BRIEF-A's BRI (hot) or MI (cold) composite,[11] whereas Broletti et al.[5] who also used the BRIEF-A, relied on the global executive composite (GEC), which places greater emphasis on cold EF subscales. Additionally, performance-based EF measures, used by Järvinen et al.[19] may be dependent on motor abilities, and they may not fully capture the EF required in the real-world.[29,37]

The results of this study also indicated a higher frequency of cold EF deficits compared to hot EF deficits, with nearly twice as many participants exhibiting challenges in cold EF functions. The deficits were primarily observed in Initiation, Task monitoring, Working memory, Planning and organizing, and Organization of materials – affecting 30–40 % of the sample, aligning with the literature.[13–15,29,38] This suggests that for many adults with DCD, cognitive regulation in task-oriented settings is a primary challenge that may hinder their daily functioning.

Our findings that only a small portion of the sample of adults with DCD presented with hot EF deficit, are novel. Specifically, we found a low portion of deficits in the sub-domains of Inhibition, Emotional control, and Self-monitoring deficits, compared to a relatively high portion of deficit in Shifting. It should be noted that while this study identified that only 7 % of the sample experienced inhibition deficit, prior studies on inhibition deficit in adults with DCD reported mixed results.[16,38] Perhaps the difference in the studies' results stems from the fact that unlike these earlier studies, which assessed inhibition in non-emotional computer-based measures, this study examined inhibition in emotionally driven everyday behaviors, such as regulating responses (e.g., interrupting others, speaking without forethought) and difficulty stopping inappropriate actions (i.e., I have difficulties sitting still, I have difficulties waiting my turn).[11]

The literature on the EF of individuals with DCD debates whether EF is integral to motor difficulties, rather than being a secondary effect of the disorder. Mixed evidence on the relationship between motor severity and EF keeps this question open.[18,37] Our findings, showing more severe motor problems in those with co-occurring DCD and EF deficits compared to DCD alone, contribute to this ongoing discussion by suggesting that EF are strongly related to motor difficulties in DCD. However, further research is needed to explore this topic.

DCD, co-occurring EF deficits and well-being

The results of this study further indicated significant differences between adults with DCD with and without EF deficits in emotional, mental, and overall well-being aspects. These group differences suggest a contribution of EF deficits to well-being, over and above the effect of DCD. A possible explanation for these findings is that cold EF deficits disrupt individuals' performance in daily routines.[39] Difficulties with initiating tasks, remembering important details, planning task execution, along with the coordination challenges associated with DCD can create a scenario that significantly impacts an individual's ability to navigate daily life demands, potentially exacerbating well-being outcomes.

In this study, emotional well-being was operationalized as general *self-efficacy* and *self-esteem*. According to the social-cognitive theory of Bandura,[43] self-efficacy beliefs are influenced, among other factors, by the individual's success in performing tasks at varying levels of difficulty. In this context, the repeated experience of individuals with DCD and co-occurring EF deficits of not meeting functional expectations can foster reduced *self-efficacy*, regardless of task difficulty or level of success. These can be accompanied by feelings of inadequacy and worthlessness, contributing to lower self-esteem. This constant mismatch between aspirations and real-life outcomes may diminish sense of *overall well-being*, exhibited by low life satisfaction.

Furthermore, in this study, mental well-being was operationalized as the extent to which an individual experiences *psychological distress*. EF serves as a cognitive resource for the effortful control of goal-oriented cognitive operations.[9–11] Hence, when this capacity is limited, engaging in tasks that requires EF can require considerable mental exertion,[41] potentially leading to distress.[40] *Psychological distress* may also arise from perceived difficulties in daily routines among adults with DCD,[42] which are exacerbated by EF difficulties.[39]

Limitations and strengths

This study included a relatively small convenience sample and a cross-sectional design, which may impact the generalizability of our findings and the ability to conclude on the causality between EF deficits and well-being. Additionally, reliance on self-reported measures of EF may introduce bias, though these were chosen to capture everyday EF-related experiences. In addition, this study's strength was the exclusion of participants having health conditions other than DCD that are characterized by core deficits in EF, especially ADHD or ADHD symptoms. Moreover, the recruitment process involved verifying current motor coordination difficulties through performance-based motor assessment.

Conclusion

This study demonstrates a notable frequency of EF deficits among adults with DCD, suggesting pervasive challenges in their daily planning and organization, initiation, shifting, working memory, and task monitoring. Yet, these deficits occurred only among half of the sample of adults with DCD, therefore, the findings support the conceptualization of EF deficits as co-occurring condition with DCD, rather than inherent component of the disorder. Nonetheless, it was found that co-occurring EF deficits contribute to poor emotional, mental, and overall well-being. These findings underscore the need for a comprehensive evaluation of both motor and cognitive aspects in intervention planning for adults with DCD, to enhance their well-being. Findings emphasize the heterogeneous nature of executive function deficits in adults with DCD, stressing the importance of interventions targeting specific EF domains, particularly cold EF aspects.

Declarations of competing interest

None

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