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The mediational role of executive functions for the relationship between motor ability and academic performance in pediatric cancer survivors

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ABSTRACT

Introduction: Pediatric Cancer Survivors (PCS) bear a high risk for late effects within motor abilities (MAs) and executive functions (EFs). In typically developing children, these domains are interrelated and predictors of academic performance. The current study investigated (i) whether MAs and EFs are also interrelated in PCS, and (ii) whether EFs mediate the relation between MAs and academic performance.
Methods: 78 PCS (7–16 years; $M = 11.23$; $SD = 2.49$) participated in this study. Three MAs were assessed: coordination and strength (using the German Motor Test) and endurance (using a cycle ergometer test). EFs were assessed: inhibition and cognitive flexibility (Color-Word Interference Test) and working memory (Block Recall test); and academic performance by questionnaire asking for children's grade point average.
Results: Pearson correlations revealed associations of coordination and strength with EFs and associations of all three MAs with academic performance. A multiple regression model revealed that among the three MAs, coordination was the only significant predictor of EFs ($\beta = 0.42$, $p = .001$). Lastly, mediation analyses revealed that the association of MAs with academic performance was mediated by EFs (indirect effect: $\beta = 0.167$, $p = .003$). Regarding individual motor abilities, this was only true for coordination and strength, but not for endurance.
Conclusion: Results show that MAs and EFs are interrelated in PCS and that EFs mediate the relationship between coordination and strength with academic performance. This may be important for the design of future physical activity interventions to improve MAs, EFs and academic performance.

1. Introduction

Pediatric Cancer Survivors (PCS) have a high risk for a variety of late effects, which include physical, motor, and cognitive functioning (Benzing et al., 2021; Robison & Hudson, 2013; Siegwart et al., 2020). Since motor and cognitive skills are known determinants of successful academic performance, it is not surprising that a recent meta-analysis revealed that PCS perform worse than their peers at each educational level (Saatci et al., 2020). However, it remains unclear to what extent children's motor and cognitive functioning contribute to academic performance in PCS.

Around 33%–40% of long-term PCS report cognitive impairments (Brinkman et al., 2016; Phillips et al., 2015; Siegwart et al., 2020). The severity of these impairments largely depends on the type of cancer and treatment (Krull et al., 2018). Cancer and its treatment are particularly harmful to higher-level cognitive processes such as executive functions (EFs) (Krull et al., 2018; Siegwart et al., 2020).

EFs refer to a multi-component construct, consisting of several distinct, yet interrelated, cognitive processes which are needed in unfamiliar, complex, and challenging situations (Diamond, 2013). EFs are thought to be comprised of three core processes (Karr et al., 2018; Miyake et al., 2000): (1) *inhibition*, which includes controlling selective

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attention and inhibiting predominant responses; (2) *cognitive flexibility*, which includes changing perspectives or shifting between mental sets; and (3) *working memory*, which includes retaining and processing information.

EFs are strong predictors of mental and physical health and academic performance (Diamond, 2013; Moffitt et al., 2011; Pascual et al., 2019). Children with poor EFs more frequently show behavioral problems and are more likely to drop out of school (Diamond, 2016; Espy et al., 2011). The authors of a recent meta-analysis showed that children with better EFs are better in school (moderate effect size) and indicated that EFs might serve as a mediator between motor abilities and academic performance (Pascual et al., 2019).

Motor abilities (also known under the related term physical fitness (Ortega et al., 2008)) represent a construct referring to the capacity to perform a variety of physical activities and movement skills (Bös et al., 2009; Lämmle et al., 2010). This construct includes several motor ability dimensions such as endurance, strength and coordination, which appear to rely on metabolic, neuromuscular, and cognitive control processes on varying degrees (Pesce, 2012; Serrien et al., 2007). According to the three-level model of Bös (2009), the basic motor abilities may be described as being either more energetically-determined (e.g., endurance) or more information-oriented (e.g., coordination), depending on their involvement of cognitive control processes.

Indeed, in typically developing (TD) children, motor abilities were found to be interrelated with EFs in multiple studies (Khan & Hillman, 2014; van der Fels et al., 2015; Van Waelvelde et al., 2020). Such findings have been explained by a) close interrelations of motor and cognitive development (Diamond, 2000); b) shared processes between cognitive and motor control (Roebers & Kauer, 2009); and c) a neural overlap between action and cognition (Serrien et al., 2007). Based on these underlying mechanisms, motor ability dimensions relying more on cognitive control processes (e.g., information-oriented), such as coordination, should be more strongly related to children's EFs than motor abilities relying predominantly on metabolic processes such as endurance.

To date, most studies have focused on the more energetically determined abilities such as endurance, and the differential contributions of multiple motor ability dimensions to EFs and academic performance have rarely been examined within the same study (Schmidt et al., 2017). However, there are few (longitudinal) studies which revealed that EFs mediate the relationship between motor abilities and academic achievement (Cadoret et al., 2018; Oberer et al., 2018; Rigoli et al., 2012; Schmidt et al., 2017; van der Niet et al., 2014). In two of them the differential contributions of endurance and coordination were investigated (Oberer et al., 2018; Schmidt et al., 2017). Notably, in both studies only (visual-) motor coordination predicted children's academic performance, fully mediated through EF performance, whereas endurance did not.

To explain the potential mechanisms underpinning the relationship between motor ability and academic achievement, different hypotheses have been brought forward. Within the *cardiovascular fitness hypothesis*, duration and intensity are considered important because it is assumed that physical activity leads to functional and structural alterations in brain areas that are relevant for EFs and learning (Khan & Hillman, 2014). Within the *cognitive stimulation hypothesis* (Best, 2010; Pesce, 2012; Tomporowski et al., 2008) and the *skill acquisition approach* (Tomporowski & Pesce, 2019), it is assumed that cognitively challenging physical activity (e.g., learning a dance sequence) engages and trains the same brain regions that are underlying EFs and learning. Given these hypotheses, the cross-sectional relationships between different dimensions of motor ability, EFs, and academic performance may provide important information about the underlying mechanisms and about which characteristics should be included in a physical activity intervention.

In particular for PCS, this may be important for the design of physical activity interventions because they suffer from late effects in both motor and cognitive functioning due to the cancer and its treatment (Benzing et al., 2021; Robison & Hudson, 2013; Siegwart et al., 2020). However, the motor and cognitive entity are mostly treated separately during recovery and only few studies have examined the link between motor abilities and EFs in this vulnerable sample during child- or adulthood (Davis et al., 2010; Gendron et al., 2020; Phillips et al., 2020; Wolfe et al., 2013). The conducted studies mostly included endurance or other individual motor ability dimensions (Gendron et al., 2020; Phillips et al., 2020; Wolfe et al., 2013), finding positive relationships with EFs. However, to our knowledge, no study has included multiple dimensions of motor ability (coordination, strength, endurance) and examined their differential relationship with EFs and academic achievement in PCS.

Therefore, the aim of the current study was to investigate whether in PCS, (i) motor abilities (coordination, strength, endurance) and EFs are interrelated; and (ii) whether motor abilities are differentially related to academic performance mediated by EFs. Considering that PCS display deficits in the motor, cognitive and academic achievements domains (Davis et al., 2010; Gendron et al., 2020; Phillips et al., 2020; Wolfe et al., 2013), we hypothesized the existence of interrelations between motor abilities and EFs, and a mediated path linking motor abilities (in particular coordination), EFs and academic performance similar to that found in typically developing counterparts (Cadoret et al., 2018; Oberer et al., 2018; Rigoli et al., 2012; Schmidt et al., 2017; van der Niet et al., 2014).

2. Method

2.1. Design and procedures

We analyzed data from the Brainfit study, which was conducted at the Children's University Hospital Bern and Zurich, Switzerland, between January 2017 and December 2018 (Benzing et al., 2018, 2020). The Brainfit study aimed to assess the efficacy of different interventions in PCS. The study was granted ethical approval by the respective cantonal ethics committees (Bern: KEK-NR. 196/15; Zurich: ZH2015-03997) and was registered at ClinicalTrials.gov (NCT02749877). The legal guardians of all participants provided written informed consent and the children provided assent to participate. All assessments were conducted at the respective hospitals. Investigators conducting the assessments were blinded with regard to the participants' medical history. Note that cross-sectional analyses including data from the Brainfit study have been reported previously (Benzing et al., 2021; Siegwart et al., 2020), however, no analyses regarding associations between MAs, EFs and academic performance in PCS were conducted so far. Therefore, cross-sectional data including background variables, EFs and motor abilities were used for these reanalyses.

3. Participants

In total, 81 PCS were recruited at two specialized pediatric university hospitals in Bern and Zurich, Switzerland. Medical data of potentially eligible participants was provided by the Swiss Childhood Cancer Registry (SCCR). Study inclusion criteria were the following: aged between 7 and 16 years; diagnosed with cancer in the past 10 years; cancer treatment (surgery, radiation, and/or chemotherapy) terminated at least 12 months prior to participation. If the cancer did not involve the central nervous system (CNS), treatment had to include either radiation or chemotherapy in addition to surgical removal of the tumor. Exclusion criteria were: (a) any neurological disease or unstable state of health, (b) substance abuse, and (c) inability to follow study procedures. The data of three PCS were excluded from analyses (relapse: $n = 1$, noncompliance: $n = 1$, language problems: $n = 1$). Thus, the final sample size was 78 (see table 1).

Table 1
Descriptives of pediatric cancer survivors including background variables, motor abilities and executive function performance.

	PCS (n = 78)		
	Mean (*SD*)	Min	Max
Socio-demographic background variables			
Age [years]	11.23 (2.49)	7.28	16.70
Biological sex [female/male]	32/46	0	1
Height [cm]	144.89 (14.43)	114.00	171.00
Weight [kg]	40.90 (14.08)	20.70	74.40
Socioeconomic status [0–9]	6.59 (1.56)	2.00	9.00
Physical activity behavior [minutes/ month]	630.73 (604.66)	0.00	3240.00
Nonverbal IQ[a]	105.99 (11.69)	82.00	136.00
Cancer related background variables			
Age at diagnosis [years]	5.38 (3.13)	0.57	12.74
Treatment duration [years]	1.34 (0.92)	0	3.63
	n (%)		
Leukemia and lymphomas	41 (52.6)	0	1
CNS tumors and neuroblastomas	17 (21.8)	0	1
Other cancer diagnoses	20 (25.6)	0	1
Surgery only	8 (10.3)	0	1
Chemotherapy only	31 (39.7)	0	1
Surgery and radiotherapy	5 (6.4)	0	1
Surgery and chemotherapy	19 (24.4)	0	1
Chemotherapy, radiotherapy and surgery	15 (19.2)	0	1
Motor abilities[b]	Mean (*SD*)		
Total score	95.18 (7.75)	78.00	113.00
Coordination	95.21 (10.87)	70.00	116.50
Strength	93.53 (9.26)	73.67	116.33
Endurance [power in watts]	105.30 (42.83)	30.00	220.00
Executive Functions			
Inhibition[c]	10.11 (3.27)	1.00	15.00
Cognitive flexibility[c]	10.31 (3.05)	1.00	14.00
Working memory[a]	100.36 (18.29)	56.00	145.00

Note. PCS = pediatric cancer survivors.
[a] Age-normed score; Mean = 100; standard deviation = 15; higher scores denote higher values on the IQ or Executive Function scale.
[b] Age-normed score; mean = 100; standard deviation = 10; higher scores denote higher values in motor abilities.
[c] Age-normed score; Mean = 10; standard deviation = 3; higher scores denote higher values on the working memory scale.

4. Measures

The following *background variables* were assessed: Age and biological sex were recorded from questionnaires. Height and weight were measured with a tape rule and a scale. Age at diagnosis, cancer type, treatment duration, and type of treatment were derived from the SCCR. Information about socioeconomic status was gathered from the parents of PCS using the family affluence scale (Boudreau & Poulin, 2008). The family affluence scale consists of four questions regarding the family wealth (e.g., whether their child has its own bedroom, the number of family-owned cars etc.). The response format varies from item to item, and points are given for example for the number of family-owned cars. The sum of the four items ranges between 0 and 9 and constitutes the prosperity index. An acceptable reliability and validity has been demonstrated (Boudreau & Poulin, 2008). Physical activity behavior was assessed using the physical activity, exercise, and sport questionnaire (Fuchs et al., 2015). Parents had to indicate the frequency and duration of up to three types of exercise that their child regularly engages in, resulting in an average number of minutes per week. Acceptable psychometric properties have been demonstrated (Fuchs et al., 2015). Nonverbal IQ was assessed using age-based standard scores (M = 100, SD = 15) of the test of nonverbal intelligence (TONI-4), fourth edition (Brown et al., 2010).

Academic performance was assessed using a single questionnaire item asking the parents for their children's grade point average (GPA). The GPA ranges between 1 and 6 with higher scores denoting a higher GPA. Previous studies suggest that reported GPA values are an acceptable and reliable school performance estimation (Kuncel et al., 2005).

Regarding EFs, inhibition and cognitive flexibility were measured using the Color-Word Interference Test of the Delis-Kaplan Executive Function System (Delis et al., 2001). Visual working memory was assessed using the Block Recall Test of the Working Memory Test Battery for Children (WMTB-C; Pickering & Gathercole, 2001). An acceptable retest reliability (Block Recall Test; r = 0.62; Color-Word Interference Test; r = 0.77) has previously been demonstrated for both tests (Delis et al., 2001; Pickering & Gathercole, 2001). Age-normed scores (WMTB-C: M = 100, SD = 15; D-KEFS: M = 10, SD = 3) were z-transformed and the mean was used as an executive function composite score.

Motor abilities were assessed using five items of the German Motor Test (Bös et al., 2009), including coordination (balancing backwards, jumping sideways) and strength (sit-ups, push-ups, long-jump), and a cycle ergometer test for endurance. The derived performance raw scores were subsequently transformed to a standardized (age and sex specific) Z-score (M = 100, SD = 10) using formula Z = 100 + 10 *. The coordination and strength scores (calculated from the mean z-scores of the test items mentioned above) were considered as dependent variables (M = 100, SD = 10). According to the test manual, Z-scores of 97.5 and below are considered as below average; scores between 97.5 and 102.5 are considered as average; scores above 102.5 are considered as above average. An acceptable validity (see manual) and reliability (r = 0.82) has been demonstrated for the German Motor Test (Bös et al., 2009). For endurance a cycle ergometer test was conducted using the Godfrey protocol (Godfrey et al., 1971) and the aeroman® professional (Aceos, Fürth, Germany). Because of technical problems with the device, 24.3% of the data was missing. Therefore, the maximal workload (power in watts), which was not affected by the technical problems, was used as endurance score. In addition, the coordination, strength and endurance scores were z-transformed and the mean was used as overall motor ability total score.

5. Statistical analyses

In total, 8.3% data was missing in the dependent variables because of a) questionnaires that were incomplete; b) assessments which could not be terminated because of time constraints; c) one person which could not participate in the motor abilities assessment because of a muscle injury. Since Little's "missing completely at random test" was not significant ($p > .05$), data was imputed using expectation-maximization (EM) algorithm. The pattern of results did not change with or without imputation. The imputed data was used for all the analyses.

To address the first question concerning the relationship of different dimensions of motor ability (coordination, strength, endurance) with EFs and academic performance, correlation and regression analyses were performed. First, partial correlations were calculated between academic performance with EFs (inhibition, cognitive flexibility, working memory) and motor abilities (coordination, strength, endurance) including age, biological sex, and socioeconomic status as covariates. To explore effects for different cancer types, additional partial correlations were performed for participants with central nervous system involvement (CNS+) and for those without (CNS-). Second, two multiple regression analyses including motor abilities (coordination, strength and endurance) as predictors of EFs were performed without (first model) and with (second model) the addition of potential confounders (age, biological sex, socioeconomic status) (Simmons et al., 2011). Since pattern of results did not change, results depict the model including all measured confounders.

To address the second question whether EFs mediate overall motor ability and its different dimensions (coordination, strength, endurance) and academic performance, four mediation analyses were performed in R using the lavaan package (Rosseel, 2012). The first included the overall motor ability total score and the other three the individual coordination, strength and endurance scores. These latter were performed to evaluate potential differences in the predictive value of individual motor abilities for EFs. All mediation models were corrected for potential confounders (age, biological sex, socioeconomic status). Note that the statistical assumptions for the multiple regression and mediation analysis (outliers, multicollinearity, normality, linearity, homoscedasticity of residuals, independence of errors) were met (Tabachnick & Fidell, 2007). Moreover, for the mediation model robust maximum-likelihood estimation with (Huber-White) standard errors were used. Level of significance was set at $p < .05$ for all analyses.

6. Results

Correlational analyses for all PCS revealed associations among motor abilities, EFs, and academic performance (see figure 1). In detail, all three dimensions of motor ability were related to academic performance. However, only coordination (*r*s: 0.154–0.422) and strength (*rs:* 0.314–0.595), but not endurance (*r*s: 0.038–0.112), showed significant correlations with EFs. Correlations for PCS with and without CNS involvement were often similar, but no clear pattern of findings can be established here (also due to the small group size). The multiple regression model (see table S1) including coordination, strength, and endurance as predictors, as well as age, biological sex and socioeconomic status as potential confounders showed that only coordination was a significant predictor of EFs ($\beta = .42$, $p = .001$).

The first overall mediation analysis testing the role of EFs in the relation between motor abilities and academic performance (see figure 2) revealed a significant indirect effect ($\beta = 0.167$, $p = .003$ [0.057, 0.278]). This model explained 30% of the variance of academic performance. The further mediation models performed with coordination and strength showed that EFs acted as mediator of their relationship with academic performance (strength: $\beta = 0.174$, $p = .006$ [0.051, 0.297]; coordination: $\beta = 0.204$, $p = .001$ [0.081, 0.328]), explaining 28% of variance each (see figure 3). This reduced the direct effect to a non-significant level. Instead, in the model including endurance, no indirect effect was found, but only a direct effect ($\beta = 0.362$, $p = .002$ [0.129, 0.595]), with 33% of variance of academic performance explained.

7. Discussion

In this study we investigated whether in PCS, (i) motor abilities (coordination, strength, endurance) and EFs are interrelated; and (ii) whether EFs mediate the relation between motor abilities and academic performance. First, the results show that motor abilities and EFs were interrelated in PCS and that among different motor abilities, only motor coordination was predictive of EFs. Second, EFs mediated the relationship between overall motor ability and academic performance. When focusing on the different dimensions of motor abilities, the association of coordination and strength with academic performance was mediated by EFs; for endurance, however, only a direct association was detected.

The detected relationship between motor abilities and EFs provide no direct evidence regarding underlying mechanisms, but they are in line with studies in TD children. These relationships may be, for example, explained by related cognitive and motor development (Diamond, 2000; Roebers & Kauer, 2009), in which similar brain regions, such as the cerebellum and the prefrontal cortex are involved (Diamond, 2000; Koziol et al., 2014). Cancer disease and treatment has a detrimental effect on brain health (Sleurs et al., 2016), including for example smaller white matter volumes in frontal-striatal and cerebellar regions known to be linked to cognitive functions and scholastic achievement (Khajuria et al., 2015; Krull et al., 2018; Reddick et al., 2014; Rueckriegel et al., 2015). Since both cognitive and motor functions rely on the interconnected activity of these brain areas, they may be implicated and related in PCS.

The detected relation of EFs with coordination and strength, but not endurance deserves further discussion. This finding is contradictory to several studies reporting positive relationships in TD children between endurance and EFs (Khan & Hillman, 2014; Van Waelvelde et al., 2020). However, in PCS, late effects occur in particular in cognitive functions, such as attention or EFs (Siegwart et al., 2020; Sleurs et al., 2016). It thus seems plausible that motor abilities that are more relying on these functions (which all include cognitive control processes), and thus showing a conceptual overlap with EFs (Roebers & Kauer, 2009), are more strongly related to EFs. This hypothesis is supported by the result of the regression analysis, suggesting that within the different motor ability dimensions, coordination (the dimension likely relying the most on cognitive control) plays a pivotal role, which is in line with studies in other pediatric patients (Abgottspon et al., 2021). In fact, coordination was the only predictor among the different motor ability dimensions, which explained a significant amount of variance in EFs.

Results of the partial correlations for children with CNS involvement compared to those without show no clear pattern of differences and in many cases, relationships appear to be similarly strong. Although the inclusion criteria was that children had direct damage to the CNS, or indirect consequences due to radiotherapy or chemotherapy, participants of the current study represent a heterogenous group of PCS. In the current study, due to the small sample, it was only possible to explore the partial correlations between children with CNS involvement and those without. Future studies need to investigate the relationships between MAs and EFs in further detail considering different cancer types and treatments in larger samples.

The overall results of the mediation analyses are in line with studies in TD children, finding that EFs mediate the relationship between motor abilities and academic performance (Cadoret et al., 2018; Oberer et al., 2018; Rigoli et al., 2012; Schmidt et al., 2017; van der Niet et al., 2014). In addition, we confirmed that also in PCS motor coordination was mediated through EF performance. Given these findings and the fact that in TD children physical exercise has shown to have a positive effect on EFs and school performance (Álvarez-Bueno et al., 2017; Pesce et al., 2021), the results of this study indicate that further studies on the effect of physical exercise interventions particularly focusing on motor coordination, EFs and academic performance in PCS are needed.

In contrast to Schmidt et al. (2017) and Oberer et al. (2018), in the current study not only motor coordination, but also the effect of strength on academic performance was fully mediated through EF performance. To speculate, since strength is considered to rely on both metabolic and cognitive control mechanisms (Bös et al., 2009; Lämmle et al., 2010), strength may be more important for EFs and school performance in populations with deficits such as PCS than in TD children (Benzing et al., 2021). Well-designed physical activity interventions targeting coordination and muscular strength, could contribute to a successful development and help to improve cognitive functions and academic performance.

8. Limitations

However, these conclusions come with three caveats. First, the effects reported are purely correlational. Therefore, as done in TD children and other clinical populations (Benzing & Schmidt, 2019; Egger et al., 2019; Schmidt et al., 2017), also in PCS interventional studies targeting motor abilities and EFs are needed to investigate their effect on academic performance. Second, since parent-reported GPAs might be more biased with respect to school performance tests, the results of the study have to be treated cautiously. Third, the mediational analyses were calculated separately for each motor ability dimension and included a composite score for EFs rather than each core EF separately. Multiple mediation models increase risks for type I error of multiple testing. The composite score for EFs is not optimal because evidence suggests that the neural systems underlying inhibition, shifting, and working memory consist of overlapping yet distinct networks (McKenna et al., 2017). Unfortunately, a more complex model did not converge due to small

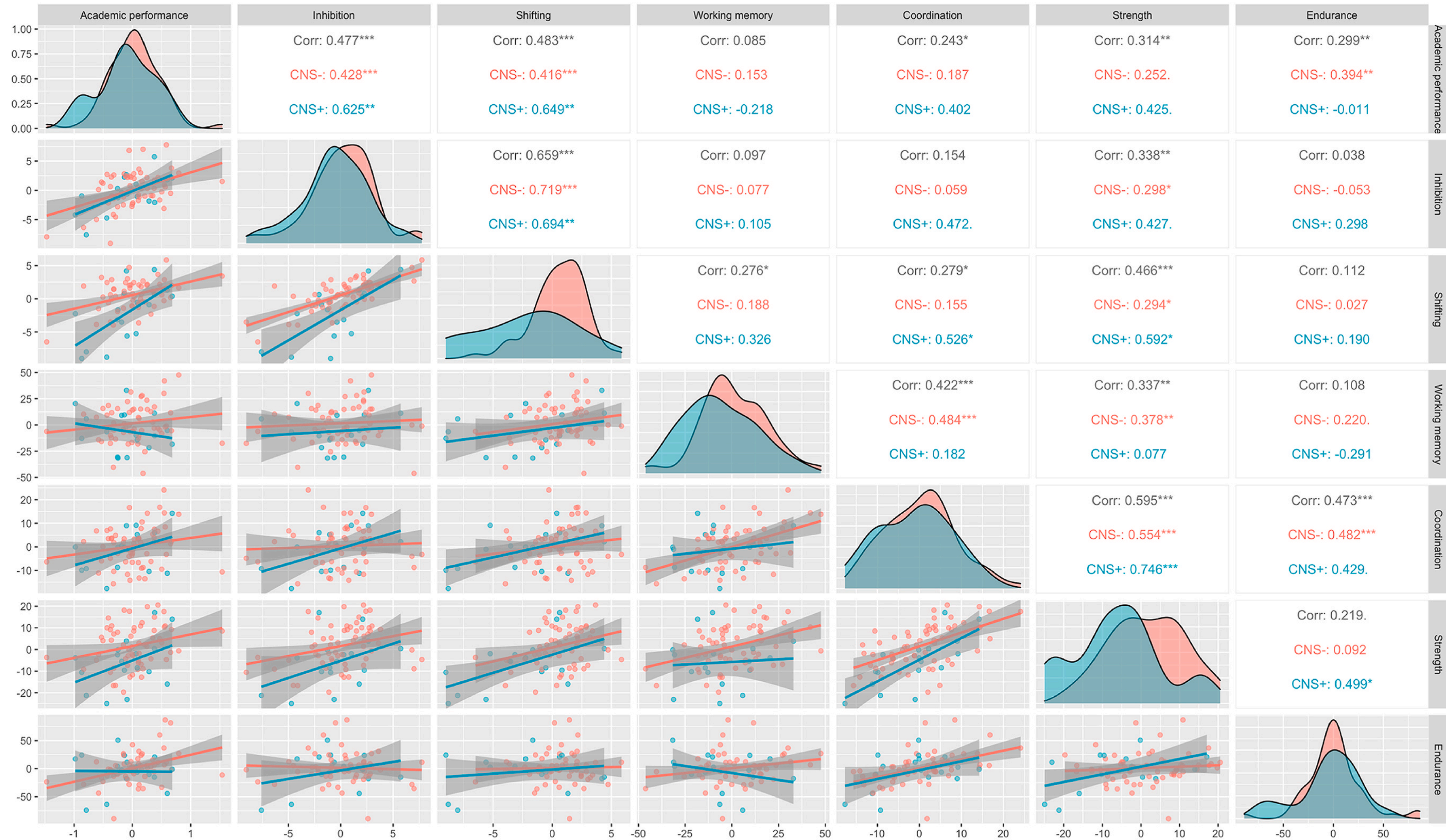

Figure 1. Partial correlations between academic performance, inhibition, shifting, working memory, coordination, strength and endurance (control variables: age, biological sex, socioeconomic status).
Note. Scatterplots show unstandardized residuals of the regressions underlying the partial correlations. Corr refers to the overall correlation including pediatric cancer survivors with and without central nervous system involvement; CNS- is the correlation for the pediatric cancer survivors without central nervous system involvement; CNS+ is the correlation for the pediatric cancer survivors with central nervous system involvement.

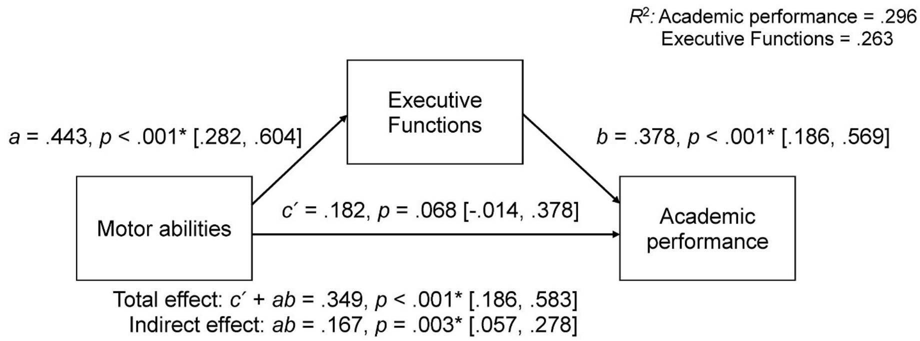

Figure 2. Mediation analyses between motor ability, executive functions and academic performance in pediatric cancer survivors.
Note. R^2 represents the proportion of the explained variance by the model; a, b, c' refer to the respective paths of the mediation model; for each path standardized parameter estimates, significances and standardized confidence intervals (in square brackets) are indicated; path c' represents the direct effect.

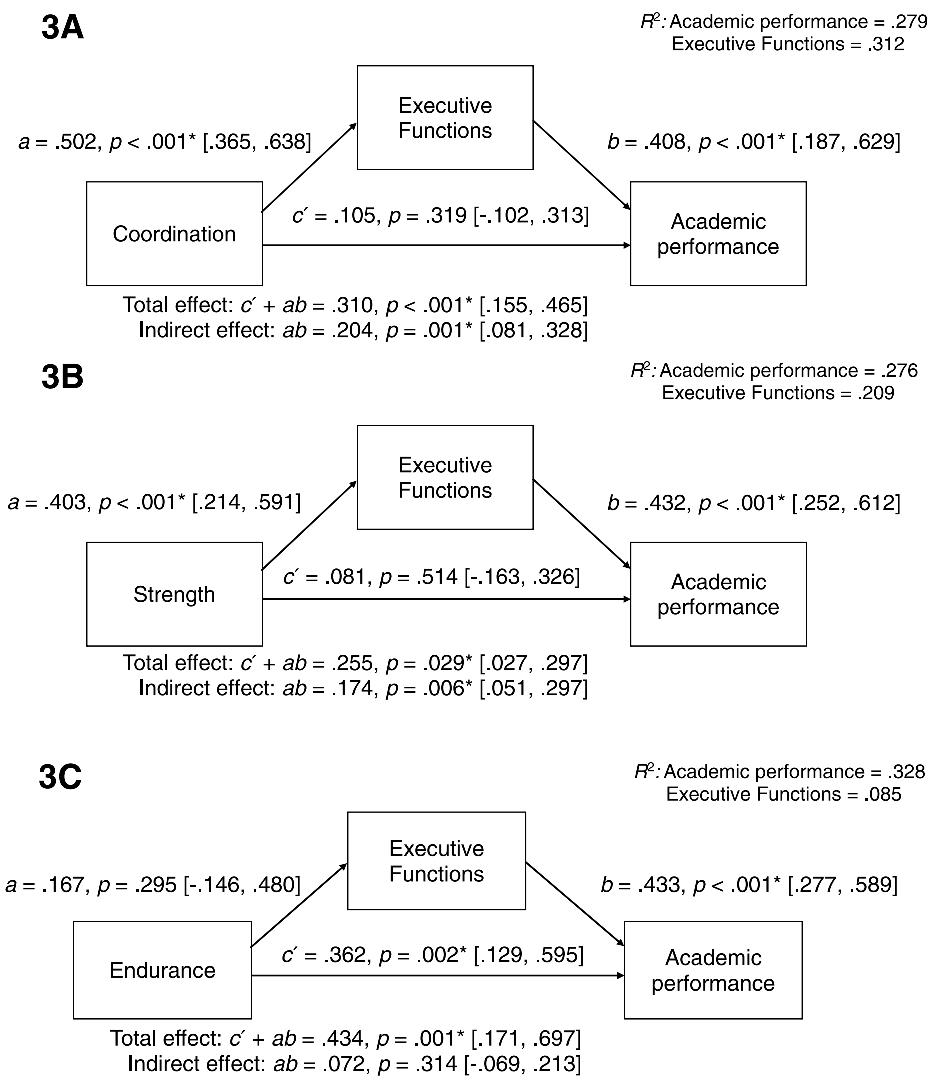

Figure 3. Separate mediation analyses for different motor ability dimensions [coordination (3A), strength (3B), endurance (3C)], executive functions and academic performance in pediatric cancer survivors.
Note. R^2 represents the proportion of the explained variance by the model; a, b, c' refer to the respective paths of the mediation model; for each path standardized parameter estimates, significances and standardized confidence intervals (in square brackets) are indicated; path c' represents the direct effect.

sample size. Nevertheless, PCS are a vulnerable study group, in which the relationships between motor ability, cognitive functions, and academic achievement have rarely been investigated. We therefore are certain that the results of this study are valuable for research (e.g., design of interventions) and clinical practice (e.g., assessment of deficits and rehabilitation).

9. Conclusion

Besides the need for future studies as outlined in the limitations section, we suggest monitoring the motor abilities and EFs in the aftercare of PCS. Furthermore, based on interventional studies in TD children and on the results of the current study showing close relationships between coordination, strength, EFs and academic performance, motor ability interventions may have the potential to benefit motor abilities, EFs and/or academic performance also in PCS.

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Author contributions

Conception or design of the work: JS, KL, MS, MG, MSc, RE, VB; acquisition of data: JS, RE, VS, VB.; data analysis: SA, VB; interpretation of data for the work: KL, MS, MSc, RE, SA, VB; draft of the work: SA, VB. All co-authors revised the work critically for important intellectual content and approved the final version of the manuscript. Furthermore, all co-authors are accountable for all aspects of the work ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethical approval

This study was conducted in the cantons of Bern and Zurich, Switzerland, between January 2017 and December 2018. It was granted ethical approval by the respective cantonal ethics committees (Bern: KEK-NR. 196/15; Zurich: ZH2015-03997) and was registered at ClinicalTrials. gov (NCT02749877).

Declaration of competing interest

The authors do not have any conflicts of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2022.102160.

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