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Motor coordination problems and psychological distress in young adults: A test of the Environmental Stress Hypothesis

Yao-Chuen Li[a,b,c], Matthew Y.W. Kwan[a,b], John Cairney[a,d,*]

[a] INfant and Child Health (INCH) Lab, Department of Family Medicine, McMaster University, Hamilton, ON L8S 4L8, Canada
[b] Department of Kinesiology, McMaster University, Hamilton, ON L8S 4L8, Canada
[c] Child Health Research Center, Institute of Population Sciences, National Health Research Institutes, Zhunan, Miaoli County 350, Taiwan
[d] Faculty of Kinesiology and Physical Education, University of Toronto, Toronto, ON M5S 2W6, Canada

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ABSTRACT

Background and aims: The Environmental Stress Hypothesis (ESH) has been used to examine how the relationship between poor motor coordination and psychological distress is affected by physical health and psychosocial factors. However, work applying the ESH is still limited, and no studies have used this framework with adults. The current investigation aims to examine the association between motor coordination and psychological distress among emerging adults, and examine potential mediators to this relationship based on the ESH.

Methods: 225 young adults aged 17–23 years completed a survey of motor coordination, physical activity, secondary stressors (i.e., general stress and global relationships), perceived social support, self-concept, and psychological distress. Structural equation modeling was conducted to examine mediating pathways and overall model fit.

Results: The final model of the ESH showed good model fit ($x^2 = 83.24$, $p < .01$; RMSEA = 0.056; NNFI = 0.927; CFI = 0.954; GFI = 0.947), and indicated that the relationship between poor motor coordination and psychological distress was mediated by secondary stressors, perceived social support, and self-concept.

Conclusions: This study highlights the effect of poor motor coordination on psychological distress in young adults, and suggests that interventions should target psychosocial well-being, in addition to motor coordination, to prevent psychological distress.

What this paper adds?

This study was conducted to enhance our understanding of the mechanisms of psychological distress in young adults with motor difficulties based on the Environmental Stress Hypothesis (ESH). In the paper, we focus specifically on the mediating effects of physical activity, BMI, and psychosocial factors on the relationship between motor difficulties and psychological distress in young adults. This study was the first to simultaneously test multiple mediating pathways identified in the ESH in this population. The results of the study have identified several modifiable risk and protective factors, namely general stress, global relationships, perceived social support and self-concept, that could be targeted in future intervention studies to improve psychological well-being in young adults with motor coordination problems.

* Corresponding author at: Faculty of Kinesiology and Physical Education, University of Toronto, 55 Harbord Street, WSB 2044, Toronto, ON, M5S 2W6, Canada.
E-mail address: john.cairney@utoronto.ca (J. Cairney).

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1. Introduction

A number of recent studies have found a relationship between poor motor coordination and mental health problems within community-based samples (Lingam et al., 2012; Rigoli et al., 2017; Wagner, Jekauc, Worth, & Woll, 2016). Specifically, children with motor coordination problems, such as Developmental Coordination Disorder (DCD), have been found to be at greater risk for internalizing problems, such as depression and/or anxiety, compared to their typically developing peers (Missiuna et al., 2014; Piek, Bradbury, Elsley, & Tate, 2008; Skinner & Piek, 2001). This may be due to the fact that their motor difficulties interfere with tasks or activities of daily living both at home and school (APA, 2013) and further result in a number of other adverse outcomes, such as negative self-perceptions (Skinner & Piek, 2001), reduced physical activity participation and poor health- related physical fitness (Cairney & Veldhuizen, 2013). As motor coordination problems early in life are likely to track into adolescence and adulthood, they have also been linked to symptoms of psychological distress later in life (Piek, Barrett, Smith, Rigoli, & Gasson, 2010; Sigurdsson, Van Os, & Fombonne, 2002). However, little work has examined the specific reasons or mechanisms behind why children with motor coordination problems are at risk for mental health issues.

The Environmental Stress Hypothesis (ESH) was developed based on Pearlin's Stress Process model, which provided a flexible, generic framework to understand the mediating and/or moderating variables that connect stress to emotional consequences (Pearlin, 1989; Pearlin, Menaghan, Lieberman, & Mullan, 1981). Cairney and colleagues subsequently modified the general model to include pathways hypothesized to be salient factors that could explain the complex inter-relationships between motor coordination problems and internalizing problems, such as depression and anxiety (Cairney, Rigoli, & Piek, 2013). In the ESH, internalizing problems are considered to be mediated and/or moderated by other physical (i.e. physical activity and overweight/obesity) and psychosocial (i.e. interpersonal conflicts, perceived social support, and self-concept) factors (Cairney et al., 2013). According to this model, DCD is considered a primary stressor that initiates a cascade of other stressors (i.e., interpersonal conflicts), which negatively impacts other psychosocial and behavioral risk factors known to be associated with increased symptoms of internalizing problems (Cairney et al., 2013). For example, it is hypothesized that interpersonal conflicts or poor social relationships may result in lower perceived social support and negative self-concept, which in turn lead to increased risk for anxiety or depression (Cairney et al., 2013). Physical inactivity and obesity, both of which are considered to be consequences of DCD (Cairney & Veldhuizen, 2013), may further deteriorate peer relationships, perceived social support and self-concept, and lead to greater risk for internalizing problems in children with DCD (Cairney et al., 2013).

Despite evidence from a recent review supporting some of the underlying pathways in the ESH (Mancini, Rigoli, Heritage, Roberts, & Piek, 2016), there are still significant knowledge gaps with regard to empirically testing the pathways identified in the model. To date, a limited number of studies have directly examined the relationship between motor coordination problems and internalizing problems based on the ESH (Li et al., in press; Mancini et al., 2016; Mancini, Rigoli, Roberts, Heritage, & Piek, 2017; Rigoli, Piek, & Kane, 2012; Wilson, Piek, & Kane, 2013). For example, in a recent study using a community-based sample of children and youth, Li et al. (in press) found that the relationship between children at risk for DCD and internalizing problems could be sequentially mediated by physical activity, BMI or global self-worth. Rigoli et al. (2012) and Mancini et al. (2016, 2017) have also identified the mediating effects of self-perceptions and perceived social support on the relationship between poor motor coordination and internalizing problems in Australian preschool and school-aged children.

Although prior longitudinal research has also indicated that in both clinical and community populations, motor coordination difficulties at early ages would have direct effects on emotional or mood problems in adolescence (Wagner et al., 2016), or indirect effects through social communication skills (Harrowell, Hollen, Lingam, & Emond, 2017), our understanding of the impact of poor motor coordination on internalizing issues in other populations, specifically young adults, is limited (Rigoli et al., 2017). Moreover, all potential mediators identified in the ESH (e.g. stress, perceived social support, or self-competence) have yet to be comprehensively tested in any age group. This includes the direct effects of physical activity and Body Mass Index (BMI) on internalizing problems (Biddle & Asare, 2011; Hoare, Skouteris, Fuller-Tyszkiewicz, Millar, & Allender, 2014). There is evidence that physical activity may have both a direct effect on internalizing problems and may also mediate the relationship between DCD and internalizing problems, in part through its influence on other risk and protective factors. For example, a recent study by McIntyre, Chivers, Larkin, Rose & Hands, 2015 showed that exercise improved self-perceptions in adolescents with poor motor competence. Li et al. (in press) also found that physical activity mediated the association between DCD and internalizing problems, but only in school-aged girls (Li et al., in press). To our knowledge, no research has investigated the impact of both physical activity and BMI simultaneously on mental health problems.

Both motor difficulties and internalizing problems (symptoms of depression and anxiety) have been found to track from childhood through adolescence into adulthood (Rasmussen & Gillberg, 2000). Findings from a 10-year longitudinal study found that the 16-year-old adolescents who were originally diagnosed as "clumsy" at the age of 6 still experienced difficulties with motor coordination and reported lower participation in physical education classes while in high school. This same group was also found to have lower physical self-concept and more emotional and behavioral problems when compared to their typically developing peers (Losse et al., 1991; Rasmussen & Gillberg, 2000). Despite motor coordination problems likely persisting beyond the transition out of high school, little research has focused specifically on young adults with these problems (Hill & Brown, 2013; Kirby, Sugden, Beveridge, & Edwards, 2008). More research investigating the relationship between motor coordination problems and internalizing problems during the early adulthood period is needed, and the ESH may be a useful framework to begin to understand the predictors of mental health problems during this developmental period.

The purpose of the present study is to examine the relationship between motor coordination problems and psychological distress among emerging adults and to explore underlying mechanisms identified in the ESH (i.e., the mediating pathways through physical

activity, BMI, and psychosocial factors). Based on the ESH, we hypothesized that lower levels of motor coordination would be associated with physical inactivity and higher BMI in young adults, all of which further increase their general stress and poor social relationships. These primary and secondary stressors would further erode social and personal resources, and consequently, be associated with increased psychological distress.

2. Material and methods

2.1. Participants and design

This was a cross-sectional study of undergraduate students at a mid-size Canadian university who were recruited for the current study between January and April 2016. A total of 241 students agreed to participate and responded to the online survey. Participants with intellectual disability, neurological/musculoskeletal disease, or physical impairments contributing to significant motor difficulties were excluded from the study (n = 1, 0.4%). Data with evidence of potential response bias (e.g., answers were all the same) or incomplete data (> 50% missing values) were also excluded (n = 15, 6.2%). After applying the exclusion criteria, the final study sample included 225 participants (93.4%). The mean age of the final sample was 19.5 years (SD = 1.0, range = 17 to 23), and the majority were female (75.1%), in their first year of study (53.8%), and recruited from the School of Science (53.0%). Ethical approval was obtained from the Institutional Research Ethics Board.

2.2. Procedures

Participants were recruited from three sources: (1) posters placed around campus and postings on social media; (2) announcements made in undergraduate classes; and (3) recruitment stations in university residences. Eligibility was confirmed using a screening email to exclude participants with any neurological/musculoskeletal disease and visual impairment. Intellectual disabilities were not formally measured in this study because we assumed that people attending higher education would not have severe intellectual impairments (Kirby et al., 2008). Participants were then provided with a secure online link to complete a survey. The first section of the survey assessed participants' demographic information (e.g., sex, date of birth, height, and weight). Participants then completed a series of items measuring motor difficulties, physical activity, stress and global relationships, perceived social support, self-concept, and internalizing problems. It took participants approximately 40 min to complete the questionnaires.

2.3. Measures

2.3.1. Outcome – psychological distress

The 6-item Kessler-6 (K6) scale was developed to measure non-specific psychological distress based on extensive psychometric analysis using item response theory methods across sociodemographic subsamples (Kessler et al., 2002). In this study, we do not use the term "internalizing problems" in reference to adult mental health. Depression and anxiety are clinical diagnoses whereas the term "psychological distress" is used to describe symptoms of negative affective and anxiety (Pearlin, 1989). To be consistent with the literature, we adopt the latter term for this study. The K6 scale asked respondents to self-report the frequency (none of the time to all of the time), which they felt nervous, hopeless, restless, depressed, worthless, and that everything was an effort in the past 30 days. Each response was scored from 0 to 4, yielding a total score ranging from 0 to 24 with higher scores indicating a greater risk for psychological distress. The K6 scale has been found to have excellent internal consistency (Cronbach's α = 0.89–.92), and precisely discriminate individuals with an anxiety disorder, mood disorder, or non-affective psychosis from those without these problems in the community population with discrimination accuracy of 0.88 (Kessler et al., 2002). Internal consistency within our sample was very good (Cronbach's α = 0.84).

2.3.2. Primary stressor – motor coordination problems

The Adult Developmental Coordination Disorder/Dyspraxia Checklist (ADC) was developed to screen for adults with DCD over 16 years of age (Kirby, Edwards, Sugden, & Rosenblum, 2010). The 40-item ADC consists of two subscales, which ask respondents to report the frequency (0 = never, 1 = sometimes, 2 = frequently, and 3 = always) of childhood motor difficulties (Section 1) and current difficulties with motor tasks and activities of daily living (Section 2). The total score is the sum of two section scores, with higher scores indicating greater motor difficulties. An individual is identified as having possible DCD if they show past motor difficulties in childhood (score ≧17 in Section 1) and have a total score of ≧65. However, in the absence of diagnostic criteria and objective assessment of motor coordination (Hands, Licari, & Piek, 2015), this study used a continuous variable of self-reported motor coordination problems (i.e., the total scores of the ADC) as an alternative to a dichotomous classification of DCD commonly used to describe severe motor coordination problems. Cronbach's α of the ADC subscales ranged from 0.87 to 0.91, indicating excellent internal consistency (Kirby et al., 2010). Construct validity and concurrent validity against the Handwriting Proficiency Screening Questionnaire have also been tested by Kirby et al. (2010). Internal consistency for the ADC total scale and subscales in the current study were 0.76 for Section 1, 0.88 for Section 2, and 0.90 for the full scale.

2.3.3. Potential mediators

2.3.3.1. Physical activity. The International Physical Activity Questionnaire-Long Form (IPAQ-LF) was used to measure physical activity (Booth, 2000). The IPAQ-LF is a 7-day recall self-reported questionnaire investigating habitual physical activity in 15- to 69-

year-old youths and adults, and has proven to have good test-retest reliability (Spearman ρ = 0.81) and criterion validity when compared against accelerometry (Craig et al., 2003). It consists of 27 questions covering five domains: job-related physical activity (7 items), transportation physical activity (6 items), domestic physical activity (6 items), leisure-time physical activity (6 items) and time spent sitting (2 items). In this study, total time spent in physical activity across four domains ranged between 30 min/week and 4500 min/week. Time spent in each activity is recorded and then converted to metabolic equivalent minutes per week (MET- min/week). The sum of MET-min/week in each activity was calculated to be representative of total physical activity and used for analysis in this study.

2.3.3.2. BMI. Participants were asked to self-report body height (in either cm or ft/in) and weight (in either kg or lb). The units were further converted, where necessary, into cm for height and kg for weight to calculate BMI (kg/m2). Self-reported BMI is considered to be a proxy measure of body composition. It is commonly used in community samples and has been found to be highly correlated with objectively-measured BMI (r = 0.87–.95) (McAdams, Van Dam, & Hu, 2007).

2.3.3.3. Secondary stressors. Two measures were used to assess general stress and global relationships that were representative of secondary stressors in this study (i.e., interpersonal conflicts in the ESH). A measure of chronic strains (ongoing problems) from the National Population Health Survey (Cycle 1) was used to measure general stress (Statistics Canada, 2007). Participants were asked to indicate (yes or no) to 11 items if they experienced stress in the domains of interpersonal relationships, finances, work/school and personal and familial health. Internal consistency of this questionnaire was 0.69 in this study. Furthermore, the Experiences in Close Relationships – Relationship Structures (ECR-RS) was used to measure stressors related to intimate relationships in this study (Fraley, Heffernan, Vicary, & Brumbaugh, 2011). The self-report ECR-RS was designed to assess two dimensions: attachment-related anxiety (e.g., I'm afraid that other people may abandon me) and avoidance (e.g., I usually discuss my problems and concerns with others). The ECR-RS includes nine items (three items for attachment-related anxiety and six items for attachment-related avoidance). Composite scores and total score were calculated by averaging the total item scores in each subscale and all questions, respectively; higher scores indicate poorer or strained relationships. The ECR-RS has demonstrated high internal consistency in previous studies (Cronbach's α = 0.80–.88), and there is empirical support for aspects of construct validity (e.g., factor structure and sex differences in reporting) (Fraley et al., 2011). Internal consistency of the ECR-RS was good in this study (Cronbach's α = 0.87 for avoidance domain and 0.89 for anxiety domain).

2.3.3.4. Social and personal resources. Self-esteem (six items) and mastery (seven items) were based on the work of Rosenberg (1965) and Pearlin et al. (1981), respectively (Pearlin et al., 1981; Rosenberg, 1965). These scales are commonly used in stress process studies as core psychosocial resources (Bovier, Chamot, & Perneger, 2004; Pearlin et al., 1981). Self-competence was measured using the 8-item self- competence subscale of the Self-Liking and Self-Competence Scale – Revised Version, reduced from the original 20-item instrument assessing global self-esteem (Tafarodi & Swann, 1995, 2001). Confirmatory factor analysis identified construct, convergent, and discriminative validity of the scale in undergraduate students, and specifically, the subscale of self-competence showed satisfactory internal consistency and 3-month test-retest reliability (Tafarodi & Swann, 2001). These three scales were used to measure components of perceived self-concept. Respondents were asked to indicate the degree to which they agree or disagree with each statement using a five-point adjectival scale (from 1 = strongly agree to 5 = strongly disagree). The total score for each component was calculated by summing the item scores, with higher scores indicating higher levels of self-concept (i.e., self-esteem, mastery and self-competence respectively). The values of Cronbach's α were 0.64 for self-esteem, 0.62 for mastery, and 0.80 for self-competence in this study. Despite lower internal consistency of the scales for self-esteem and mastery, the overall Cronbach's α was 0.82 when all items in three scales were included to capture global self-concept.

The Multidimensional Scale of Perceived Social Support (MSPSS) was also included in this study (Zimet, Dahlem, Zimet, & Farley, 1988). Participants were asked to answer 12 questions covering three different domains: support from family, friends, and a significant other. Respondents responded to each item using a seven-point Likert scale from 1 (very strongly disagree) to 7 (very strongly agree). The subscale and total scores were calculated by averaging the item scores in each subscale and the whole test, respectively, with higher scores indicating higher levels of perceived social support. This questionnaire has been validated in adolescents and young adults aged 17–22 years with a high internal consistency (Cronbach's α = 0.85–.91) and test-retest reliability (r = 0.72–.85) (Zimet et al., 1988). Internal consistency of the MSPSS in this study was excellent for each domain (Cronbach's α = 0.91–.93) and the full scale (Cronbach's α = 0.93).

2.4. Data analysis

Descriptive statistics and Pearson correlation coefficients were computed for the study variables using SPSS 22.0 for Windows (Armonk, NY: IBM Corp). Structural equation modeling (SEM) was conducted using AMOS 21.0 (Chicago: IBM Corp) to test mediating pathways and overall model fit of the ESH.

2.4.1. Data preparation

Six cases with incomplete or invalid data were first excluded. Missing data analysis was then conducted using SPSS. The results indicated that there were no variables with more than 5% missing values (0–3.4%) and that the pattern of missing data was random (i.e., MCAR). We first calculated z-scores to identify outliers for each variable. After the data were visually inspected for outliers ($|Z| \geq 3$) (Kline, 2015), nine cases were further excluded because of invalid data on physical activity (e.g., doing activities that totalled

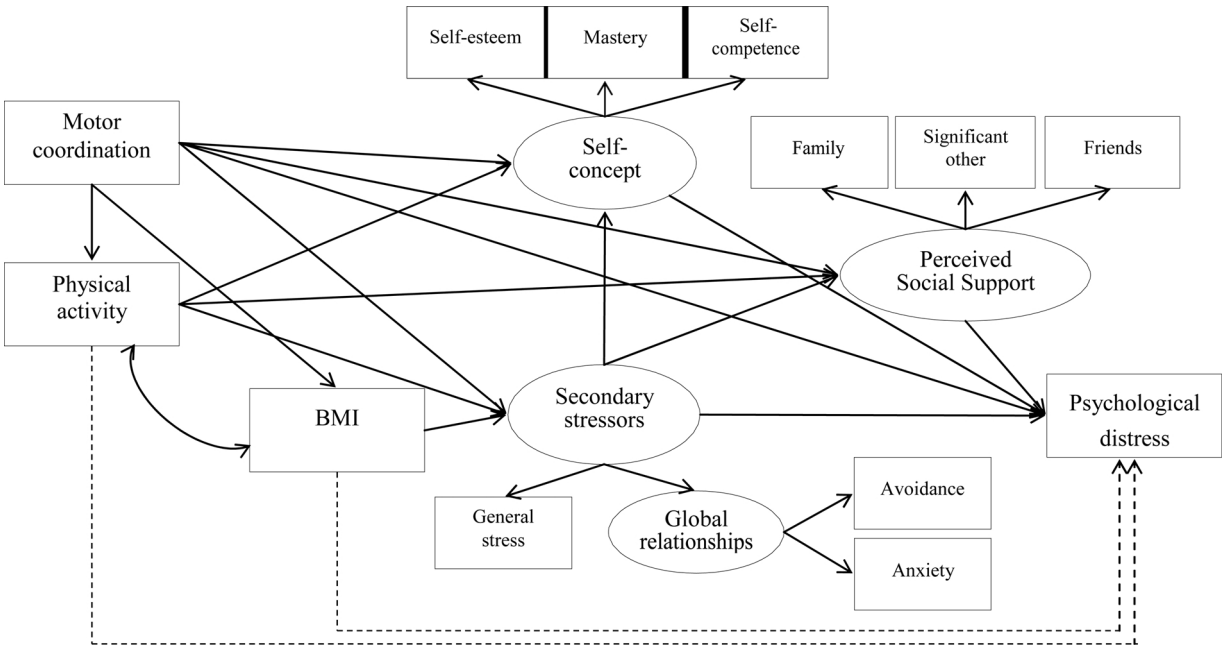


Fig. 1. The original and extended ESH.

more than 24h a day). Based on the results of missing value analysis, single regression imputation was used to estimate the missing values for variables with missing values, including body height and weight, time spent in different domains of physical activity, and items scores for all other measures (i.e., K6, ADC, ECR-RS, MPSSS, and scales for self-concept). Taking into account the potential sex effect on the variables measured in this study, the missing values were imputed for males and females separately. The normality of variables was finally examined, and correlation/covariance matrix was prepared for the SEM analysis.

2.4.2. Structural equation modeling

SEM with maximum likelihood estimation was used to test the full ESH model, which consisted of three latent measurement models of secondary stressors with three indicators (i.e., general stress, avoidance and anxiety of global relationships), one latent factor for perceived social support with three indicators (i.e., perceived social support from family, friends, and a significant other), and a latent self-concept factor with three indicators (i.e., self-esteem, mastery, and self- competence), along with several path models indicating different mediating pathways. Model fit for the three measurement models was first examined. The overall model fit of the original ESH was then reviewed (solid-line pathways in Fig. 1). Model fit indices were examined and reported, and model fit was considered satisfactory if the following criteria were met: (1) $p > .05$ for x^2 statistics, (2) root mean square error (RMSEA) < 0.06, (3) Tucker-Lewis index (TLI) > 0.90, (4) comparative fit index (CFI) > 0.90, and (5) goodness-of-fit index (GFI) > 0.90 (Hu & Bentler, 1999).

Secondly, two direct pathways from physical activity and BMI to psychological distress were added separately and simultaneously (dash-line pathways in Fig. 1), and model fit was re-examined. The comparison of a chi-square statistics and CFI between hierarchical models was used to identify if the extended ESH including pathways from physical activity and BMI to psychological distress was better than the original model. The statistically significant improvement in model fit is set at $p < .05$ for Δx^2 statistics and/or ΔCFI > 0.01 (Cheung & Rensvold, 2002).

3. Results

3.1. Sample characteristics

The means and standard deviations of all variables are provided in Table 1. Pearson correlation coefficients showed that motor coordination problems were significantly associated with all psychosocial variables and psychological distress (all p's $< .05$): poor motor coordination was related to higher psychological distress, higher general stress, poorer global relationships, lower perceived social support, and negative self-concept (i.e., self-esteem, mastery, and self- competence). Both physical activity and BMI were not significantly correlated (i.e., $p > .05$) with any of the other variables except for the following: physical activity was correlated with general stress ($r = 0.142$, $p < .05$) and perceived social support from a significant other ($r = -0.139$, $p < .05$). All psychosocial variables were significantly inter-related (all p's $< .01$; See Table 1 for correlation coefficients).

Table 1
Descriptive statistics and correlation matrix.

	Mean	SD	Correlation coefficients											
			1	2	3	4	5	6	7	8	9	10	11	12
1. ADC	22.0	13.2												
2. K6	8.8	4.9	.297											
3. IPAQ-LF	39.8	39.0	−.030[a]	−.037[a]										
4. BMI	22.3	3.7	.005[a]	−.005[a]	.102[a]									
5. General stress	3.5	2.3	.180	.472	.142	.047[a]								
6. GR-avoidance	3.5	1.3	.193	.293	.048[a]	.072[a]	.216							
7. GR-anxiety	4.3	1.7	.283	.479	.024[a]	.062[a]	.304	.183						
8. PSS-SO	5.5	1.5	−.174	−.230	−.139	−.101[a]	−.220	−.412	−.261					
9. PSS-Fam	5.2	1.4		−.256	−.071[a]	−.095[a]	−.333	−.348	−.296	.550				
10. PSS-Fri	5.5	1.2	−.114[a]	−.328	−.040[a]	−.054[a]	−.214	−.505	−.277	.591	.483			
11. Self-esteem	21.5	3.4	−.238	−.458	−.010[a]	−.002[a]	−.190	−.352	−.370	.339	.351	.423		
12. Mastery	19.9	4.1	−.168	−.547	−.007[a]	.028[a]	−.346	−.221	−.402	.267	.292	.293	.241	
13. Self-competence	23.8	4.7	−.312	−.522	.076[a]	.114[a]	−.303	−.301	−.331	.211	.252	.320	.539	.444

[a] $p > .05$; ADC, Adult DCD/Dyspraxia Checklist; GR, Global Relationships; IPAQ-LF, International Physical Activity Questionnaire-Long Form; K6, Kessler-6; PSS, Perceived Social Support (SO, significant other; Fam, Family; Fri, Friends).

3.2. Structural equation modeling

3.2.1. Measurement models for latent variables: stress, perceived social support, and self- concept

The results of the normality test showed that neither severe skewness (|skewness| > 3) nor severe kurtosis (|kurtosis| > 10) was found for any of the variables (Kline, 2015), and thus no transformations were needed. The measurement models of perceived social support and self- concept were just-identified (df = 0), with the saturated models showing perfect model fit. The model for secondary stressors was underidentified (df = −1). Therefore, in order to render this latent variable analyzable, the equality of constraint was imposed on the loadings from the latent factor to general stress (Kline, 2015). By doing so, this model became just-identified and saturated, which was appropriate for the SEM analysis.

3.2.2. Testing the ESH

The original model of the ESH was initially tested, and model fit indices did not show satisfactory model fit ($x2 = 117.86$, $p < .001$; RMSEA = 0.077; NNFI = 0.864; CFI = 0.911; GFI = 0.929; Table 2). Therefore, modification index (MI) and standardized residuals (SR) were examined to guide the re-specification of the model. These indicators suggested two modifications: (1) correlating the error terms between perceived social support from friends and avoidance of global relationships (MI = 9.48, SR = −2.90); and (2) correlating errors between self-esteem and mastery (MI = 15.90, SR = −2.06) (Schermelleh-Engel, Moosbrugger, & Müller, 2003). Both suggested modifications were supported by previous studies showing a negative association between overall perceived social support and avoidance (Wilson & Gore, 2013) and a positive association between self-esteem and a sense of mastery (Erol & Orth, 2011), and we, therefore, re-specified the model making these changes. The modified model showed improvements in model fit indices ($x2 = 83.24$, $p < .01$; RMSEA = 0.056; NNFI = 0.927; CFI = 0.954; GFI = 0.947) indicating a better fit to the data when compared to the first model.

As shown in Fig. 2, the significant relationship between motor coordination and psychological distress (unstandardized estimate = 0.112, S.E. = 0.024, $p < .001$) was mediated by secondary stressors and perceived social support, including a one-mediator pathway through secondary stressors and two sequential mediating pathways: the first through secondary stressors and perceived social support (motor coordination → secondary stressors → perceived social support → psychological distress); and the second through secondary stressors and self-concept (motor coordination → secondary stressors → self-concept → psychological distress).

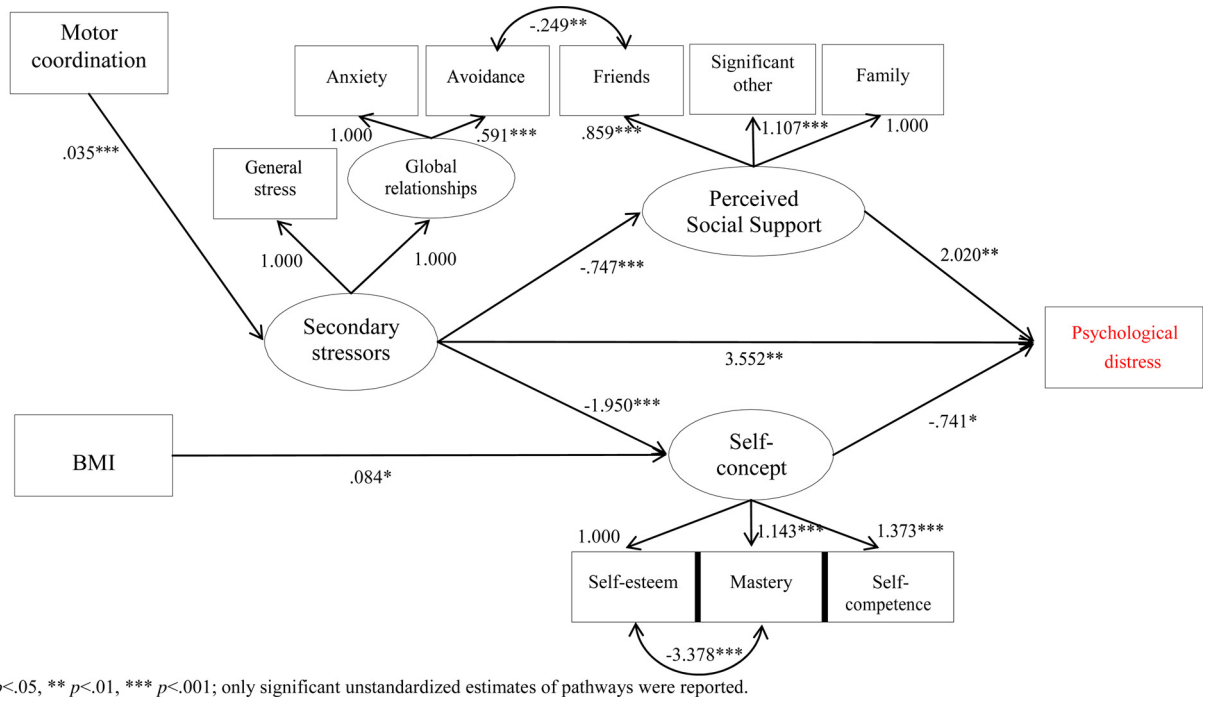
3.2.3. Testing of the extended ESH

Three additional extended models (Extended Model 1 and 2 in Table 2) were then tested. The differences in $x2$ statistic and CFI

Table 2
The goodness-of-fitness indices in all models.

	x^2 (df, p value)	RMSEA	TLI	CFI	GFI	Δx^2 (Δdf, p)	ΔCFI
Original Model	117.86 (51, $p < .001$)	0.077	0.864	0.911	0.929		
Modified Model	83.24 (49, $p < .01$)	0.056	0.927	0.954	0.947		
Extended Model 1	81.47 (48, $p < .01$)	0.056	0.927	0.955	0.948	1.77 (1, $p > .05$)[a]	0.001[a]
Extended Model 2	82.89 (48, $p < .01$)	0.057	0.924	0.953	0.948	0.35 (1, $p > .05$)[a]	0.001[a]

Extended Model 1: modified model with the pathway from physical activity to psychological distress.
Extended Model 2: modified model with the pathway from BMI to psychological distress.
[a] Compared to Modified Model.



*p<.05, ** p<.01, *** p<.001; only significant unstandardized estimates of pathways were reported.

Fig. 2. The modified ESH.

were estimated and compared to the modified original model to identify if the extended models showed significant improvement in model fit over the model shown in Fig. 2. The results showed that none of the extended models provided a better fit to the data than the modified original model (all p's > .05 for $\Delta x2$ statistics and all ΔCFI < 0.01), indicating that there were no direct effects of physical activity (Extended Model 1 in Table 2; unstandardized estimate = −0.011, S.E. = 0.009, p = .21) or BMI (Extended Model 2 in Table 2; unstandardized estimate = −0.057, S.E. = 0.097, p = .56) on psychological distress.

4. Discussion

This study is one of the most comprehensive examinations to date investigating multiple pathways in the ESH in any age group. By this we mean, while other studies have focused more narrowly on specific pathways in the ESH using longitudinal and/or experimental designs, this present study was the first to attempt to assess all domains represented in the original ESH model (Cairney et al., 2013). The findings are promising and generally provide support the conceptual framework of the ESH. Poorer motor coordination is associated with increased psychological distress, high stress levels, poor global relationships, low perceived social support, and low self-concept (including self-esteem, mastery, and self-competence) in young adults. Moreover, stress, perceived social support, and self-concept mediate the relationship between motor coordination and psychological distress during emerging adulthood.

Internalizing problems, such as increased symptoms of depression and anxiety, are evident in children with poor motor coordination, including those with DCD, across different age groups (Missiuna et al., 2014; Piek et al., 2008; Skinner & Piek, 2001). Consistent with a recent study of 18–30 year-old adults from a community sample (Rigoli et al., 2017), this study demonstrated that poorer motor coordination was associated with higher psychological distress in young adults aged between the years of 17 and 23. Although limited, previous research has shown that adults with poor motor coordination consistently reported having higher levels of depression and anxiety and perceived lower quality of life across several domains (e.g., physical health, work, and social relationships) (Hill & Brown, 2013; Hill, Brown, & Sophia Sorgardt, 2011).

The results of this study indicate that the effect of motor coordination problems on psychological distress in emerging adults may be better accounted for by differences in psychosocial well-being (i.e., general stress, global relationships, perceived social support, and self-concept), rather than physical activity and BMI. Some of these same mediating pathways have been identified in preschoolers, school-aged children, and adolescents in previous studies. For example, self-competence, specifically social competence, was found to mediate the relationship between poor motor abilities and higher emotional symptoms in preschool Australian children (Wilson et al., 2013), whereas poor social relationships (e.g. peer victimization or bullying), lower self-esteem, and social competence mediated the relationship between motor difficulties in DCD and internalizing problems in school-aged children (Campbell, Missiuna, & Vaillancourt, 2012; Lingam et al., 2012). Self-concept (but not physical self-worth) and perceived social support have also been found to mediate the relationship between motor coordination and mental health in community adolescent or adult samples (Mancini et al., 2016; Rigoli et al., 2012; Rigoli et al., 2017). It is worth noting that these previous studies only investigated a single mediator

pathway, which might over-estimate the impact of self-worth on psychological problems.

In contrast to previous results in children and adolescents with motor difficulties who have been found to be more physically inactive and unfit compared to their coordinated peers (Kwan, King-Dowling, Hay, Faught, & Cairney, 2016; Li, Wu, Cairney, & Hsieh, 2011), young adults with higher reported motor coordination problems in this study were not more likely to be physically inactive or have higher BMI relative to adults who reported no or fewer coordination problems. According to the skill-learning hypothesis (Wall, 2004), the gap in physical activity and fitness, particularly overweight/obesity, between children with and without motor difficulties should increase over time (Stodden et al., 2008). However, the gap in physical activity and weight status (i.e., BMI *herein*) does not mediate the relationship between motor difficulties and psychological distress in this age group. Several possible explanations are might be operative.

First, overall low levels of physical activity in this age group may produce a floor effect (i.e., not enough variability in physical activity in both groups), which makes it difficult to detect a mediational effect. Indeed, about 40% of our participants (41.4% in females and 39.3% in males) failed to meet recommended guidelines for physical activity (i.e. 150 min/week of moderate-to-vigorous physical activity). Secondly, young adults with poor motor coordination may recognize their motor difficulties and, in turn, withdraw from structured social physical activities (e.g. team sports) (Kirby et al., 2008), but choose instead individual activities that are less skill-demanding, competitive, and formal, such as exercising or working out in a gym, swimming, or jogging (Jarus, Lourie-Gelberg, Engel-Yeger, & Bart, 2011; Poulsen, Ziviani, & Cuskelly, 2008). In this sense, physical activity across levels of motor coordination reflects differences in the type of activity, not overall participation.

With regard to BMI, when the adult cutoff criteria for weight status was applied (i.e., BMI $\geq$25 for overweight and BMI $\geq$30 for obesity) (Centers for Disease Control and Prevention, 2016), 70.2% of our participants (71.0% for females and 67.9% for males) had normal weight, whereas 14.7% (11.8% for females and 23.2% for males) and 4.0% (4.1% for females and 3.6% for males) were categorized into overweight and obesity, respectively. Despite a range of BMI found in our sample (a nearly normal distribution: skewness = 1.13 and kurtosis = 2.22), a relatively small sample size may potentially limit our ability to detect the impact of overweight/obesity on the relationship between motor difficulties and psychological distress. Further research is needed to test if the mediation of BMI on this relationship would emerge by enlisting a larger sample size.

The results of this study should be considered in light of some limitations. The first concern focuses on motor coordination assessment, and the specific use of a self-report tool versus direct motor assessment. Even though a few standardized tests of motor competence/ability can be applied to emerging adults, none of them are considered a criterion standard to identify adults with DCD (Hands et al., 2015). Further research may be able to enlist adults with a diagnosis of DCD in childhood to test the model and investigate if the underlying pathways may differ between the community and clinical or diagnostic samples. However, it should be noted that, even though young adults with motor coordination problems (e.g., DCD) may be under-represented in this study, Cairney et al. (2013) and others (e.g., Mancini et al., 2016) acknowledge that the relationship between motor coordination problems and internalizing problems or psychological distress may not be limited to children or adults who score in the clinical range. Rather, there may be a continuous relationship between motor ability and psychological distress, which is better captured by considering the full range of motor coordination, not just low end functioning at a clinical level. The results of this study support that position. In addition, potential responses and recall biases inherent to self-report measure of the ADC may not be ruled out in this study, and this may lead to a discrepancy in the results between objective and subjective measures of motor coordination. Similarly, as participants in this study self-reported the levels of physical activity and body height and weight, the subjective measures of physical activity and BMI may impact the accuracy of the assessment. Future research should also include the objective measures of these variables. The third limitation is the asymmetry of the sample with regard to sex. During the recruitment, young female undergraduate students were more inclined to respond the survey. Future research should recruit more men in order to test the effect of sex on model fit of the ESH, and ensure that the group size is large enough ($n > 100$) to detect sex differences (Kline, 2015). Finally, the cross-sectional study design limits our ability to make statements regarding causality. Ideally, a prospective cohort study with a large sample size beginning in early childhood will provide more robust evidence regarding the potential long-term changes in these relationships proposed within the ESH.

5. Conclusions

This study contributes to our understanding of the underlying mechanisms that might account for the effect of motor coordination problems on psychological distress in young adults. More importantly, the mediating pathways identified in this study highlight the importance that the evaluation for young adults with potential motor coordination problems should be taken into account from a holistic perspective as motor difficulties are associated with poorer psychosocial well-being and higher level of psychological distress. It also provides practical implications to guide interventions. Our results suggest that motor coordination problems may not only affect physical, but psychosocial health as well. For young adults with poor motor coordination, the provision of psychological counseling services, programs targeting reducing general stress or providing social support, should be considered alongside other interventions (e.g., physiotherapy), which are more commonly associated with treating motor coordination problems. Such interventions may work to improve global relationships and self- concept, along with motor ability.

Conflicts of interest

None.

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