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Resarch article

Cognitive Performance, Quality and Quantity of Movement Reflect Psychological Symptoms in Adolescents

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Abstract

The presentation of unhealthy psychological symptoms are rising sharply in adolescents. Detrimental lifestyle behaviours are proposed as both possible causes and consequences. This study set out to compare selected measures of quality and quantity of movement between adolescents with and without unhealthy psychological symptoms. Using a cross sectional design, 96 participants completed the study from a whole year group of 166, age (13.36 ± 0.48) male 50.6% from a secondary school in Oxfordshire, England as a part of a larger study (EPIC) between January and April 2018. Measures were taken of quality and quantity of movement: reaction/movement time, gait pattern & physical activity, alongside psychological symptoms. Differences in movement behaviour in relation to psychological symptom and emotional problem presentation were determined using ANOVA. In the event of a significant result for the main factor of each parameter, a Bonferroni -corrected post hoc test was conducted to show the difference between categories in each group. Results for both unhealthy psychological symptoms and emotional problems were grouped into four categories ('Close to average', 'slightly raised', 'high' and 'very high'). Early adolescents with very high unhealthy psychological symptoms had 16.79% slower reaction times ($p = 0.003$, $\eta_p^2 = 0.170$), 13.43% smaller walk ratio ($p = 0.007$, $\eta_p^2 = 0.152$), 7.13% faster cadence ($p = 0.005$, $\eta_p^2 = 0.149$), 6.95% less step time ($p = 0.007$, $\eta_p^2 = 0.153$) and 1.4% less vigorous physical activity ($p = 0.04$, $\eta_p^2 = 0.102$) than children with close to average psychological symptoms. Early adolescents with very high emotional problems had 12.25% slower reaction times ($p = 0.05$, $\eta_p^2 = 0.081$), 10.61% smaller walk ratio ($p = 0.02$, $\eta_p^2 = 0.108$), 6.03% faster cadence ($p = 0.01$, $\eta p^2 = 0.134$), 6.07% shorter step time ($p = 0.007$, $\eta p^2 = 0.141$) and 1.78% less vigorous physical activity ($p = 0.009$, $\eta p^2 = 0.136$) than children with close to average emotional problems. Different movement quality and quantity of was present in adolescents with unhealthy psychological symptoms and emotional problems. We propose movement may be used to both monitor symptoms, and as a novel therapeutic behavioural approach. Further studies are required to confirm our findings.

Key words: Psychological symptoms, emotion, reaction time, gait, Flanker, physical activity, adolescents.

Introduction

There is increasing presentation of psychological symptoms in children and adolescent, elevating societal concerns about possible causes and consequences. One in five children worldwide experience mental health problems (Kieling et al., 2011). The most common symptoms are those of anxiety and depression. Approximately one in ten young people currently have a mood disorder in the United Kingdom (Green et al., 2004) and the United States (Merikangas et al., 2010). A systematic review by Bor et al, 2014 demonstrated that internalizing problems is increasing in adolescent girls but not so clearly in boys (Bor et al., 2014). Psychological symptoms and emotion differences is described by Rottenberg and Gross in (2003) (Rottenberg and Gross, 2003), who describe emotion as a "*storm*" while psychological symptoms are more like a "*seasonal climate change*". Basically emotion is a harmonized reaction to an important motivation, and causes an explicit behaviour which is short term and could disappear with losing the motivation. Unhealthy psychological symptoms form slowly and have a longer-term effects (Rottenberg and Gross, 2003).

This study used the Flanker task as a measure of cognitive control in early adolescents. There are several studies, which support that cognitive control, and psychological symptoms are interrelated with mood affecting performance during different cognitive tasks including reaction time (Peretti, 1998; Reveillon, 2018).; Reaction time (RT) is recording the time between a stimulus and response, typically including both thinking and movement time (Donders, 1868-1869). As such, RT measured by flanker task is an indicator of the inhibition of movement responses /and vulnerability to distractions. The Flanker task requires capacity of resisting distraction and "interference control" (Sanders and Lamers, 2002; Scharinger et al, 2015). These capabilities make the flanker task a suitable tool to assess cognitive control of movement in adolescents. Although there are limited studies exploring emotions and cognitive control in 9-11 year olds' (Reveillon, 2018).

Darwin was one the first researchers which in 1872 investigated the association between human emotions and movement in "*The Expression of the Emotions in Man and Animals*" (Darwin, 1872). More recent studies by Michalak et al. (2009) and Gross et al., (2012) showed that emotions affect movement patterns. Lemke et al., (2000) found that gait speed and stride length were 15.5 and 6.3% less, respectively, for individuals with major depressive disorder compared with control individuals (Lemke et al., 2000).

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Evidence suggests that children and adolescents who are more physically active, experience lower levels of psychological symptoms such as, anxiety, depression and mood difficulties, and have a higher self- esteem rather than less active children and adolescents (Ekeland et al., 2005). Moreover, in support of the direction of causality, a review of reviews about physical activity and psychological symptoms shows that conducting routine physical activity can reduce depression and improve self-esteem, cognitive performance and academic achievement in children and adolescents (Biddle and Asare, 2011). However, whether individuals with low mood move less or moving less leads to low mood has not been established.

Finally there is a strong inter- relationship between cognitive functioning and movement quality and quantity strongly evidenced in adults (Meester et al., 2014; Verlinden, 2014) which implicate the importance of the body mind axis with emerging evidence of a relationship during childhood and adolescence (review of exercise on cognition) (Biddle and Asare, 2011; Hogan et al., 2013). Again, the direction of causality is unclear and complicated by individual, family, community contextual and personal factors.

Considering the evidence to date, and underpinning understanding of these inter-relationships, we hypothesize that young people with unhealthy psychological symptoms, particularly emotional problems will react slower, move slower and subsequently perform less vigorous physical activity. In this study unhealthy psychological symptoms including emotional problems, will be evaluated alongside measures of movement quality and quantity in a whole year group of adolescents.

Methods

Design

A Cross sectional study design used in this study to assess the reflection of psychology symptoms on selected measures of quality and quantity of movement in adolescents.

Population

All of the participants recruited from year 9 average age of 13.36 (± 0.48) of an urban UK school as a part of the Engagement, Participation, Inclusion and Confidence in Sport study (EPIC) with clinical trials.gov identifier (NCT number): NCT03150784. This study was part of the screening phase of the EPIC at baseline and included four different assessments including the Flanker test for reaction time; a gait test, a physical activity assessment and the Strengths and Difficulties Questionnaire (SDQ).

Ethical approval granted by Oxford Brookes University Ethical Advisory Committee (UREC 140844). Additional authorization obtained from the school's head teacher to recruit participants, and written consent collected from each participant's parent or legal guardian.

Measures

Evaluation of unhealthy psychological symptoms and emotional problems: The Strengths and Difficulties Questionnaire (SDQ) is a validated screening tool for evaluating psychological symptoms including emotional and behavioural problems in children and adolescents (Goodman, 1997; 2001). This study used the English original youth 11-17 self-report version with 25 questions, which evaluates 5 factors: Conduct Problems, Hyperactivity/inattention, Emotional symptoms, Peer relationship problems and prosocial scales (Goodman, 1997; 2001). Total psychological symptoms scores calculated using all but the prosocial scale (Goodman, 1997; 2001). In line with the recommendations, this study utilized 4 main factors (Conduct Problems, Hyperactivity/inattention, Emotional symptoms, Peer relationship problems) for calculation of psychological symptoms.

The resultant score ranges from 0 to 40. Scores divided into 4 categories ('Close to average' (0 - 14), 'slightly raised' (15 - 17), 'high' (18 - 19) and 'very high' (20 - 40)). Participants with higher scores have the higher level of psychological symptoms (Goodman, 1997; 2001).

For assessment of emotional problems, the same scoring method used based on the (not true, somewhat true and certainly true) answers for the five emotional questions in the SDQ questionnaire. The questions included; (Often complains of headaches, stomachaches or sickness, Many worries or often seems worried, Often unhappy, depressed or tearful, Nervous or clingy in new situations, easily loses confidence, Many fears, easily scared) (Figure 1). The Emotional problem scores were categorized according to 4 different levels: ('Close to average' (0 - 4), 'slightly raised' (5), high' (6) and 'very high' (7 - 10)) (Goodman, 1997; 2001).

Cognition

Flanker test: The Flanker task (Eriksen and Eriksen, 1974) has been used in numerous studies, and can be broadly referred to as a cognitive control task which measures a person's capability to focus on the task and respond appropriately(Casey et al., 2005). For assessing total RT, congruent RT, incongruent RT and average RT during the test, a modified version of the Flanker test was used (Eriksen and Eriksen, 1974). On each trial, adolescents were presented an array of five blue fish pictures consisting of a central picture (target stimulus) surrounded by two pictures on each side of it (flankers). The task consists of 5 practice and 25 main trials. The test contains 4 trial types: same direction (congruent: ≪≪<≪ or ≫≫>≫) or the opposite direction (incongruent: ≪><≪ or ≫<>≫). In the current study, 52% of the tasks were congruent and 48% of tasks were incongruent. A trial starts with a blank screen for 500ms, followed by the stimulus array for 500ms and another blank screen for 1684ms. Responses within 500ms and 1500ms after stimulus onset considered valid (Eriksen and Eriksen, 1974). Researchers asked the study participants to sit in front of a laptop computer. A skilled researcher explained the instruction for them. According to this study instruction, participants had to use their both index fingers to click on left or right arrow buttons on keyboard if the fish in the middle was facing to the left or right. Data for each

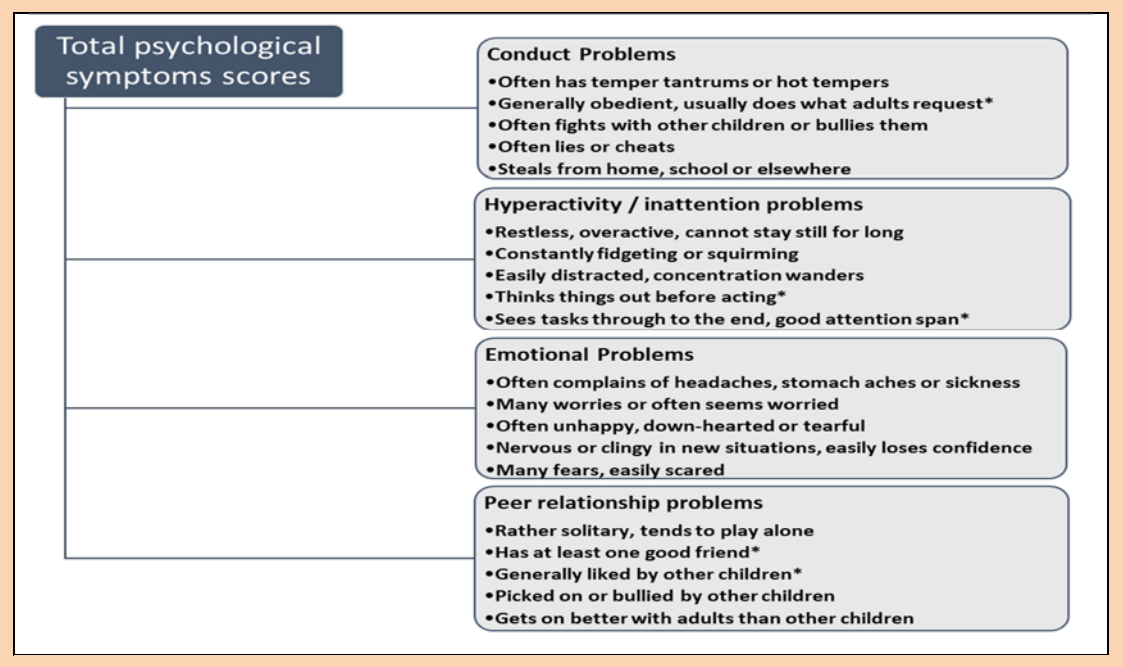

Figure 1. Strengths and Difficulties Questionnaire items and groupings. * SDQ items are scored on a 0-2 scale (not true, somewhat true, certainly true). Items denoted here with '*' are reversely scored.

participant recorded in an excel spreadsheet and total RT, Average of RT, Congruent RT and Incongruent RT calculated for all the participants.

Movement

Gait: Gait assessed by administering an instrumented standardized 10-metre walk test, whereby participants were instructed to walk from standing, at their self-selected walking pace to a 10-metre line where they were instructed to stop and remain standing still for an additional 2 seconds. Participants were instrumented by an inertial measurement unit (LPMS-B2, Life Performance Research, Japan) attached over the projected centre of mass located over the 4th lumbar vertebra (Esser et al., 2009). Acceleration transformed to vertical positioning, driving an inverted pendulum model to derive both temporal (cadence [steps/min], step time [ms]) and spatial gait parameters (stride length [m], and walking speed [m/s]) (Esser et al., 2009; Esser, 2011). Walk ratio, described as the stride length to cadence ratio [mm/ (steps/min) was derived as an indicator of motor control (Lowe et al., 2019). Gait data was standardized with the participants height and feet size using a lab view program (DataGait V11.1) developed by Oxford Brookes University.

Physical activity

Accelerometer: This study used objective method for assessment of physical activity. Daily amount of sedentary behaviour and physical activity time measured using the Axivity AX3, a "wrist-worn" tri-axial accelerometer designed by Open Lab, Newcastle University, UK. AX3 data was downloaded using OMGUI software (open movement [V.1.0.0.37]). Physical activity data was processed and analysed in 1-second epochs using a lab view program developed in Oxford Brookes University. Philips cut points were used for data analysis: Right wrist (Sedentary: < 6, Light: 6 - 21, Moderate: 22 - 56, Vigorous: >56) and Left wrist (Sedentary: < 7, Light: 7 - 19, Moderate: 20 - 60, Vigorous: > 60). The minimum valid wear time for inclusion in the analysis was at least 10 hours per day on at least three-week days and at least one weekend day for any data collection (Rich et al., 2013). Sleep time removed from the data each day between 10 pm and 6 am (Meredith-Jones et al., 2016). To control for differences in accelerometer wear time, the proportions of time spent in each type of behaviour (Sedentary Time (ST), Light Physical Activity (LPA), Moderate Physical Activity (MPA), Vigorous Physical Activity (VPA), Moderate and Vigorous Physical Activity (MVPA)) used in the analyses. Absolute minute data derived from AX3 accelerometer are presented in Supplementary Tables 1 and 2 for descriptive purposes. All participants complied with the monitoring protocol and provided at least three week days and one weekend day of AX3 data during each measurement period. Any days with missing data (due to monitor removal) treated as missing data, and the mean time and proportion of time spent in each behaviour were calculated from the remaining data (Mansoubi et al, 2016).

Procedure

All of the year 9 students in a local Oxfordshire school issued an accelerometer (AX3) on 22/1/19. Devices distributed and explained by students' tutors and collected the following week. AX3 unique ID number matched to each student's name on the school register then matched to our unique ID numbers. Participants used the wristband accelerometer (AX3) for 7 days. Data collected during the school term and at the same time for all the participants.

Anthropometric

Anthropometric measures were taken which included height (measured using a portable stadiometer, Seca UK), shoe size (participant shoes), leg length (measured using anthropometry tape measure from Anterior Superior Iliac

spines (ASIS) to medial malleolus) and body weight and composition (measured using a Tanita Body Composition Analyzer, model: HD386 portable scales, Tanita, UK).

Data analysis

All the data coded anonymously. The Shapiro-Wilk test confirmed that all data were normally distributed. For the AX3 data, the mean proportions of times spent in each behaviour calculated for each domain (waking hours). Also reaction time and different gait parameters results were calculated and separately compared between early adolescents with no psychological symptoms and early adolescents with symptoms.

The main research question, which was the differences in cognitive and movement outcomes among adolescents with varying degrees of unhealthy psychological symptoms and emotional problems were addressed using Anova. In the event of a significant result for the main factor of each parameter, Bonferroni -corrected post hoc test were undertaken to determine where the significant differences occurred. $P < 0.05$ considered significant and all tests were 2-tailed. All statistical analyses performed using SPSS version 25 (IBM SPSS Statistics). Data are displayed as mean (± SD), p values, effect size and mean (95% CI) in the text and/or tables.

Results

Total of 166 participants with the average age of 13.36 (± 0.48), 50.6 % male, between January and April 2018 were recruited for the study from a whole year group of students. Only those who completed the four tests were included (Flanker test for reaction time, Gait test, Physical Activity assessment and SDQ) leaving a final sample of 96 participants (47 Boys (Height: 1.69 ± 0.09; Weight: 57.35 ± 14.02) and 49 Girls (Height: 1.63 ± 0.11; Weight: 57.34 ± 11.23)). Study result grouped based on the participants' unhealthy psychological symptoms (N total = 86 valid) and emotional problems (N = 92 valid). At least 42 participant were required for the study. This was based on assuming 1-beta = 0.95, alpha = 0.05 and effect size $|\rho| = 0.50$ (Cohen, 1988).

Categories of Unhealthy psychological symptoms and Emotional problem

Results for both of the unhealthy psychological symptoms and emotional problems grouped into four categories based on their scores in SDQ questionnaire: ('Close to average', 'slightly raised', 'high' and 'very high'). Participants with higher scores had the higher level of unhealthy psychological symptoms and/or emotional problems and 'close to average' participants had the least unhealthy psychological symptoms and/or emotional problems.

Quality and quantity of movement according to unhealthy psychological symptoms

Main effect of unhealthy psychological symptoms on total RT was ($F(3,73) = 4.99$, $p = 0.003$, $\eta_p^2 = .170$). Bonferroni -corrected post hoc test showed that early adolescents with very high unhealthy psychological symptoms were 16.79% slower in total RT (P=.001) than adolescents with close to average score (see Table 1).

Main effect of unhealthy psychological symptoms on average of RT was ($F(3,73) = 5.36$, $p = 0.002$, $\eta_p^2 = 0.181$). Bonferroni -corrected post hoc test revealed that adolescent with very high unhealthy psychological symptoms were 18.67% slower in average RT ($p = 0.004$) than adolescents with close to average score (see Table 1).

Main effect of unhealthy psychological symptoms on congruent RT was ($F(3,73) = 5.07$, $p = 0.003$, $\eta_p^2 = 0.173$). Bonferroni -corrected post hoc test showed that adolescent with very high unhealthy psychological symptoms were 19.37% slower in congruent RT ($p = 0.001$) than adolescents with close to average score (see Table 1).

Main effect of unhealthy psychological symptoms on incongruent RT was ($F(3,73) = 4.97$, $p = 0.003$, $\eta_p^2 = 0.170$). Bonferroni -corrected post hoc test showed that

Table 1. Reaction time (RT) in milli-seconds according to level of (SDQ) among early adolescents.

SDQ	N	Mean (SD)	Mean Difference	95% Confidence Interval	P Value
Flanker total RT[ms]					
Close to average	56	11559.1 (1613.8)	Referent	Referent	Referent
Slightly raised	12	12360.2 (1612.7)	801.1	-305.0, 1907.1	0.153
High	6	12503.2 (1410.9)	944.1	-549.6, 2437.7	0.212
Very high	12	13499.9 (2499.6)	**1940.8***	834.7, 3046.9	**0.001**
Flanker congruent RT [ms]					
Close to average	56	445.6 (68.4)	Referent	Referent	Referent
Slightly raised	12	470.3 (54.6)	24.7	-24.2, 73.6	0.317
High	6	486.35 (49.2)	40.6	-25.4, 106.7	0.224
Very high	12	531. 9 (130.5)	**86.3***	37.4, 135.2	**0.001**
Flanker incongruent RT [ms]					
Close to average	56	482.9 (81.8)	Referent	Referent	Referent
Slightly raised	12	514.1 (85.2)	31.2	-22.3, 84.7	0.249
High	6	514.1 (67.8)	31.1	-41.1, 103.4	0.394
Very high	12	570.1 (102.3)	**87.2***	33.7, 140.7	**0.002**
Flanker average of RT [ms]					
Close to average	56	464.3 (72.2)	Referent	Referent	Referent
Slightly raised	12	492.2 (65.9)	28.0	-21.3, 77.2	1.000
High	6	500.2 (56.7)	5. 9	-30. 6, 102.3	1.000
Very high	12	551.0 (115.0)	**86.7***	37.5, 135.9	**0.004**

SDQ: Strengths and Difficulties Questionnaire. *The mean difference is significant at the 0.05 level.

Table 2. Walk ratio and other gait parameters according to level of psychological symptoms (SDQ) among early adolescents.

SDQ	N	Mean (SD)	Mean Difference	95% Confidence Interval	P Value
Walk Ratio[mm/(steps/min)]					
Close to average	52	6.7(0.8)	Referent	Referent	Referent
Slightly raised	12	5.9(1.1)	**-0.7***	-1.3, -0.2	**0.006**
High	6	6.3(0.6)	-0.4	-1.1, 0.3	0.275
Very high	10	5.8(0.6)	**-0.8***	-1.4, -0.3	**0.004**
Cadence [steps/min]					
Close to average	50	112.2(5.9)	Referent	Referent	Referent
Slightly raised	10	112.7(8.3)	0.5	-3.9, 4.9	0.826
High	6	112.5(7.9)	0.3	-5.2, 5.8	0.917
Very high	10	120.2(6.0)	**8.1***	3.6, 12.5	**0.001**
Step time [ms]					
Close to average	50	539.4(27.8)	Referent	Referent	Referent
Slightly raised	10	538.0(40.4)	-1.4	-22.1, 19.3	0.893
High	6	537.4(36.7)	-2.1	-27.8, 23.7	0.873
Very high	10	501.9(23.9)	**-37.6***	-58.2, -16.9	**0.001**
Vigorous activity proportion in total time [%]					
Close to average	50	0.6 (0.5)	Referent	Referent	Referent
Slightly raised	10	0.4(0.3)	- 0.2	-0.4, 0.04	0.107
High	6	0.2 (0.2)	**- 0.3***	-0.7, -0.01	**0.044**
Very high	10	0.2(0.1)	**- 0.3***	-0.6, -0.03	**0.012**
Vigorous activity proportion in activity level [%]					
Close to average	50	2.7 (2.0)	Referent	Referent	Referent
Slightly raised	10	1.8 (0.7)	-0.9	-2.1, 0.3	0.066
High	6	0.9 (0.8)	**-1.9***	-3.4, -0.4	**0.017**
Very high	10	1.3 (1.2)	**-1.4***	-2.6, -0.2	**0.011**

SDQ: Strengths and Difficulties Questionnaire. * The mean difference is significant at the 0.05 level.

early adolescents with very high unhealthy psychological symptoms were 18.06% slower in incongruent RT (p = 0.002) than children with close to average score (see Table 1).

Main effect of unhealthy psychological symptoms on walk ratio was ($F(3,73) = 4.37$, $p = 0.007$, $\eta_p^2 = 0.152$). Bonferroni -corrected post hoc test showed that Compare to adolescents with close to average unhealthy psychological symptoms, walk ratio [mm/ (steps/min)] was 11.94% smaller (p = 0.006) in early adolescents with slightly raised unhealthy psychological symptoms and it was 13.43 % smaller (p = 0.004) in adolescents with very high unhealthy psychological symptoms (see Table 2).

Main effect of unhealthy psychological symptoms on cadence was ($F(3,78) = 4.54$, $p = 0.005$, $\eta_p^2 = 0.149$). Bonferroni -corrected post hoc test showed that cadence [steps/min] was 7.13% faster (p = 0.001) in early adolescents with very high score than their peers with close to average score in unhealthy psychological symptoms (see Table 2).

Main effect of unhealthy psychological symptoms on step time ($F(3,73) = 4.39$, $p = 0.007$, $\eta_p^2 = 0.153$). Bonferroni -corrected post hoc test showed that step time [ms] in adolescent with very high unhealthy psychological symptoms was 6.95% less (p = 0.001) than children with close to average score (see Table 2).

Main effect of unhealthy psychological symptoms on vigorous physical activity was ($F(3,73)= 2.75$, $p = 0.04$, $\eta_p^2 = 0.102$). Bonferroni -corrected post hoc test showed that Adolescents with very high score (p = 0.011) and high score (p =0.017) in unhealthy psychological symptoms had accordingly 1.4% and 1.8% less vigorous physical activity than their peers with close to average score (see Table 2).

The daily average of AX3 wear time was (930.54 ± 8.57) [min]. Sedentary time, LPA, MPA, VPA and MVPA was calculated in minutes and proportion of the time for all the participants according to level of unhealthy psychological symptoms (SDQ total score) and emotional problems (Supplementary Tables 1 and 2).

Quality and quantity of movement according to emotional problems

Main effect of emotional problems on total RT was ($F(3,79) = 2.31$, $p = 0.05$, $\eta_p^2 = 0.081$). Bonferroni -corrected post hoc test showed that early adolescents with very high emotional problem were 12.25% slower in total RT (p = 0.045) than adolescents with close to average emotional problems (see Table 3).

Main effect of emotional problems on average of RT was ($F(3,79) = 2.82$, $p = 0.04$, $\eta_p^2 = 0.097$). Bonferroni -corrected post hoc test showed that early adolescents with very high emotional problem were 13.95% slower in average RT (p = 0.032) than adolescents with close to average emotional problems (see Table 3).

Main effect of emotional problems on congruent RT was ($F(3,79) = 2.69$, $p = 0.05$, $\eta_p^2 = 0.093$). Bonferroni -corrected post hoc test showed that early adolescents with very high emotional problem were 14.63% slower in congruent RT (p = 0.048) than adolescents with close to average emotional problems (see Table 3).

Main effect of emotional problems on incongruent RT was ($F(3,79) = 2.61$, $p = 0.05$, $\eta_p^2 = 0.090$). Bonferroni -corrected post hoc test showed that early adolescents with very high emotional problem were and 13.33% slower in incongruent RT (p = 0.010) than children with close to average score (see Table 3).

Main effect of emotional problems on walk ratio was ($F(3,79) = 3.20$, $p = 0.02$, $\eta p^2 = 0.108$). Bonferroni -corrected post hoc test showed that walk ratio [mm/(steps/min)] in adolescent with very high emotional

problems was 10.61% smaller (p = 0.034) than children with close to average score (see Table 4).

Main effect of emotional problems on cadence was ($F(3,79) = 4.08$, $p = 0.01$, $\eta p^2 = 0.134$). Bonferroni –corrected post hoc test showed that cadence [steps/min] was 6.03% faster (p = 0.020) in early adolescents with very high score than their peers with close to average score in emotional problems (see Table 4).

Main effect of emotional problems on step time was ($F(3,79) = 4.31$, $p = 0.007$, $\eta p^2 = 0.141$). Bonferroni -corrected post hoc test showed that Step time [ms] in adolescent with very high emotional problem was 6.07% less (p = 0.014) than children with close to average score (see Table 4).

Main effect of emotional problems on vigorous physical activity was ($F(3,79) = 4.15$, $p = 0.009$, $\eta p^2 = 0.136$). Bonferroni-corrected post hoc test showed that early adolescents with very high score (p = 0.014) in emotional problems had 1.78% less vigorous physical activity than adolescents with close to average score (see Table 4).

Table 3. Reaction time (RT) in milli-seconds according to level of Emotional problems among adolescents.

Emotional problem level	N	Mean (SD)	Mean Difference from Close to average	95% Confidence Interval	P value
Flanker total RT [ms]					
Close to average	60	11696.8 (1634.4)	Referent	Referent	Referent
Slightly raised	8	12154.4 (2218.1)	457.6	-1383.94, 2299.1	1.000
High	9	12216.4 (1474.7)	519.6	-1229.27, 2268.6	1.000
Very high	15	13129.5 (2385.7)	**1432.7***	20.29, 2845.04	**0.045**
Flanker congruent RT [ms]					
Close to average	60	450.5 (67.4)	Referent	Referent	Referent
Slightly raised	8	466.5 (95.1)	15.9	-64.8, 96.8	0.963
High	9	468.3 (51.1)	17.8	-58.9, 94.5	0.942
Very high	15	516.4 (120.7)	**65.9***	3.9, 127.9	**0.048**
Flanker incongruent RT [ms]					
Close to average	60	488.3 (83.3)	Referent	Referent	Referent
Slightly raised	8	503.2 (91.8)	14.9	-49.2, 79.03	0.645
High	9	504.9 (72.81)	16.6	-44.3, 77.6	0.588
Very high	15	553.4 (98.7)	**65.2***	15.9, 114.4	**0.010**
Flanker Average of RT [ms]					
Close to average	60	469.4 (72.2)	Referent	Referent	Referent
Slightly raised	8	486.6 (61.5)	15.4	-65.4, 96.3	1.000
High	9	504.9 (72.8)	17.2	-59.6, 94.0	1.000
Very high	15	534.9 (108.4)	**65.5***	3.5, 127.6	**0.032**

* The mean difference is significant at the 0.05 level.

Table 4. Walk ratio and other gait parameters according to level of Emotional problems among adolescents.

Emotional problem level	N	Mean (SD)	Mean Differences to Close to average	95% Confidence Interval	P Value
Walk Ratio[mm/(steps/min)]					
Close to average	55	6.6(0.8)	Referent	Referent	Referent
Slightly raised	7	6.2(0.8)	-0.4	-1.3, -0.5	1.000
High	8	6.2(0.8)	-0.4	-1.3, 0.4	1.000
Very high	13	5.9(0.8)	**-0.7***	-1.4, -0.03	**0.034**
Cadence [steps/min]					
Close to average	55	112.8(8.3)	Referent	Referent	Referent
Slightly raised	7	112.6 (7.1)	-0.2	-7.6, 7.2	1.000
High	8	110.8(6.01)	-2.02	-9.0, 4.9	0.892
Very high	13	119.6 (5.9)	**6.8***	1.1, 12.4	**0.020**
Step time [ms]					
Close to average	55	536.7(35.8)	Referent	Referent	Referent
Slightly raised	7	536.9(33.6)	-0.1	-34.1, 34.3	1.000
High	8	544.9(28.4)	8.1	-24.1,40.4	0.926
Very high	13	504.1(24.9)	**-32.6***	-58.9, -6.4	**0.014**
Vigorous activity proportion in total time [%]					
Close to average	60	0.6 (0.4)	Referent	Referent	Referent
Slightly raised	8	0.4(0.2)	-0.2	-0.6, 0.2	0.772
High	9	0.3(0.3)	-0.3	-0.6, 0.1	0.279
Very high	15	0.2(0.1)	**-0.4***	-0.7, -0.1	**0.012**
Vigorous activity proportion in activity level [%]					
Close to average	60	2.68 (2.02)	Referent	Referent	Referent
Slightly raised	8	1.9(1.1)	-0.7	-2.5, 1.1	0.502
High	9	1.5(1.2)	-1.2	-2.9, 0.5	0.230
Very high	15	0.9(1.2)	**-1.7***	-3.1, -0.4	**0.014**

* The mean difference is significant at the 0.05 level.

Discussion

We provide initial and novel evidence that early adolescents presenting with very high unhealthy psychological symptoms particularly emotional problems react and move slower with shorter and faster steps, and have lower levels of physical activity than those without. We propose these selected measures of quality and quantity of movement could be used to monitor symptoms. Whilst no causative relationship can be determined from this study, the elicited relationships indicate that fast and vigorous movements and activity could be targets for improving mental wellbeing particularly emotional problems in adolescents. However, considering the complexity of the problem a holistic approach to improving emotional problems in adolescents could use a synergistic approach and target all three movement target areas simultaneously.

Our current study results showed that reaction times were significantly slower in adolescents with very high unhealthy psychological symptoms and very high emotional problems rather than other adolescents. This study result was broadly consistent with other studies for example, Dillon et al, (2015), investigated the effect of flanker interference on accuracy and response time on 100 depressed participants as a main group and 40 healthy participant as a control group (Dillon et al., 2015). The study result showed that depressed participants responded more slowly and accurately than control group on incongruent task. The present study results alongside previous studies results confirm that emotional problems and psychological symptoms may potentially relate to slower responses poorer inhibition of responses and vulnerability to distractions within the executive functioning framework. This issue might have a serious effect on early adolescents' physical, academic performance and social skills. For instance, a study by Veas et al 2015 on 1398 early adolescents showed that cognitive variables have a significant influence on students' academic achievement (Veas et al., 2015). Also another study on a classroom-based physical activity, cognition, and academic achievement demonstrated that long term interventions of moderate physical activity can improve cognition and academic performance by 6 percent (Donnelly and Lambourne., 2011). Therefore designing the long-term interventions using active classroom methods and or sporting activities might be helpful in improving students' response/vulnerability to distraction and academic performance.

Another important subject that addressed in this study is evaluating the movement behaviour (gait and Physical activity) in early adolescents and comparing these behaviours in early adolescent with and without psychological symptoms. According to the current study results, walking patterns were significantly different in children with psychological symptoms and emotional problems. According to the present study result, adolescents with very high unhealthy psychological symptoms walk slower taking shorter and faster steps rather than other adolescents with close to average scores. Our approach linking gait and psychological symptoms in early adolescents is novel but our findings are consistent with other studies, which investigated movement behaviour and psychological symptoms in older age groups. For example, a study result by Gross et al., (2012) on 18 adults showed that joy and anger could increase the walking speed. On the other hand, Lemke et al., (2000) found that depressive disorder caused reduction in gait speed in participants, which is in contrast with current study finding. These differences may reflect the different types of psychological and emotional responses experienced by participants. Based on these evidences walking patterns could be a good indicator of psychological symptoms but further investigations are required in early adolescents.

Physical activity has beneficial effects on psychological wellbeing in children and young people (Harden et al., 2001; Ussher et al., 2007). According to the World Health Organization (WHO) guideline: children and adolescents, aged 5-17, need to have a minimum of 60 minutes Moderate to Vigorous Physical Activity (MVPA) per day (WHO, 2018). We observed that average MVPA in all the participants was less than these recommendations. Average (minutes) of daily MVPA for participants in our study with unhealthy psychological symptoms was 30.6 ± 13.02 for close to average, 28.5 ± 14.01 for slightly raised, 20.9 ± 7.3 for high and 22.02 ± 9.6 for very high score. (Supplementary tables of 1 and 2) This result demonstrates that level of physical activity in these adolescents is almost half of the minimum of recommended level, which highlights necessity of a behavioural change intervention for these adolescents. Furthermore, our study suggests that adolescents with high and very high psychological symptoms and emotional problems had lower level of moderate and vigorous physical activity level rather than other children. This result is consistent with the findings of Vankim et al, 2013 on 94 college students (where students who had more VPA were less likely to report poor mental health and perceived stress (Vankim et al., 2013). A recent meta-analysis by Bailey et al 2017 about the effect of physical activity on depression showed that, aerobic MVPA under supervision for multiple times per week over eight or more weeks could be an effective way of reducing depression in adolescents and young people (Bailey et al., 2018). Another study of 775 children in grades 7 and 8 showed that the physical activity level was significantly associated with adolescent's mental health, self-efficacy and resilience (Ho et al., 2015). Therefore based on the evidence and our current study, designing long time interventions to improve MVPA in adolescents might be helpful to reduce psychological symptoms and emotional problems.

The limitations of this study include having limited access to participants' social and economic status, using questionnaire (SDQ) for the assessment of psychological symptoms. Study strengths however include the novel assessment and comparison of cognitive function, objective measurement of physical activity and gait parameters in healthy early adolescents and early adolescents with different levels of psychological symptoms.

Conclusion

Our study demonstrated that early adolescents with unhealthy psychological symptoms have slower RT and different movement behaviour as reflected by walk ratio,

cadence, and step time and less vigorous physical activity intensity levels. These movement behaviours may be a target for monitoring and for interventions. We propose movement interventions could be employed alongside other therapeutic approaches such as thinking and drug therapies. Further studies are suggested for better understanding of movement behaviour and psychological symptoms in early adolescents.

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Key points

- Early adolescents with psychological symptoms have slower movement behaviour compared with other early adolescents
- Quality and quantity of Movement as measured by reaction time, gait or physical activity may be used to monitor psychological symptoms
- Focusing in quality and quantity of movement may be a novel therapeutic target for improving psychological symptoms in early adolescents.

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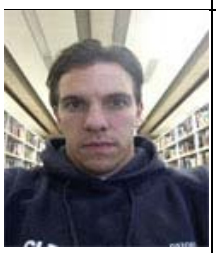

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Supplementary Table 1. Sedentary and physical activity time according to level of psychological symptoms (SDQ) among early adolescents

Psychological symptoms level	Close to average	Slightly raised	High	Very high	Total
ST[1](SD) [min]	701.9(129.4)	725.6(89.1)	684.1(119.7)	728.1(124.6)	707.6(121.9)
LPA[2] (SD)[min]	198.5(128.9)	177.5(88.3)	219.6(117.5)	182.4(121.9)	194.8(120.9)
MPA[3] (SD)[min]	25.4(9.7)	25.1(13.5)	18.9(6.6)	19.7(8.7)	24.1(10.1)
VPA[4] (SD)[min]	5.2(4.2)	3.4(2.6)	2.7(1.5)	2.3(1.3)	4.3(3.8)
MVPA[5] (SD)[min]	30.6(13.02)	28.5(14.01)	20.9(7.3)	22.02(9.6)	28.5(12.8)
ST(SD)%	75.4(13.9)	77.9(9.6)	74.01(13.1)	78.1(13.4)	76.02(13.1)
LPA(SD)%	21.3(13.9)	19.1(9.5)	23.7(12.7)	19.6(13.1)	20.9(12.9)
MPA(SD)%	2.73(1.04)	2.7(1.5)	2.1(0.7)	2.1(0.9)	2.6(1.1)
VPA(SD)%	0.6(0.5)	0.4(0.2)	0.22(0.2)	0.2(0.1)	0.5(0.4)
MVPA(SD)%	3.3(1.4)	3.1(1.5)	2.3(0.8)	2.4(1.02)	3.1(1.3)

1) ST: Sedentary Time, 2) LPA: Light Physical Activity, 3) MPA: Moderate Physical Activity, 4) VPA: Vigorous Physical Activity, 5) MVPA: Moderate to Vigorous Physical Activity

Supplementary Table 2. Sedentary and physical activity time according to level of emotional problem among early adolescents.

Emotion problem level	Close to average	Slightly raised	High	Very high	Total
ST[1](SD) [min]	693.2(130.9)	749.3(70.3)	714.8(109.4)	724.8(108.7)	705.3(121.2)
LPA[2] (SD)[min]	207.4(130.9)	156.1(66.01)	186.5(105.3)	182.9(105.9)	196.9(120.03)
MPA[3] (SD)[min]	25.5(9.8)	20.8(5.03)	22.2(7.03)	21.5(13.5)	24.1(9.9)
VPA[4] (SD)[min]	5.3(4.1)	3.3(1.9)	2.7(2.4)	1.9(1.3)	4.3(3.7)
MVPA[5] (SD)[min]	30.8(12.9)	24.1(6.7)	24.9(8.8)	23.4(14.02)	28.4(12.6)
ST(SD)%	74.4(14.04)	80.6(7.5)	77.2(11.9)	77.9(11.7)	75.8(13.03)
LPA(SD)%	22.3(14.1)	16.8(7.2)	20.1(11.4)	19.7(11.4)	21.2(12.9)
MPA(SD)%	2.7(1.1)	2.2(0.5)	2.4(0.8)	2.3(1.4)	2.6(1.8)
VPA(SD)%	0.6(0.4)	0.4(0.2)	0.3(0.3)	0.2(0.1)	0.5(0.4)
MVPA(SD)%	3.3(1.4)	2.6(0.7)	2.7(0.9)	2.5(1.5)	3.1(1.4)

1) ST: Sedentary Time, 2) LPA: Light Physical Activity, 3) MPA: Moderate Physical Activity, 4) VPA: Vigorous Physical Activity, 5) MVPA: Moderate to Vigorous Physical Activity