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Associations between physical activity intensity and well-being in adolescents

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ABSTRACT

This study aims to explore associations between physical activity intensity and well-being (i.e., positive and negative affect) in adolescents. A secondary aim was to determine if associations were moderated by sex. Grade 8 students from 14 government-funded secondary schools in low socio-economic areas of Western Sydney (Australia) were assessed. Data from three timepoints (baseline, 7–8 months, and 14–15 months) were combined to increase the sample size. Physical activity was objectively assessed for 1-week at each timepoint using Actigraph accelerometers. Time (minutes/day) in light, moderate and vigorous physical activity was estimated. The short form Positive and Negative Affect Scale for Children was used to measure well-being. Quantile regression was used to analyse the data. A total of 3140 observations were collected from 1223 students (mean age at baseline: 12.9(0.54); 55.1% male). Light and moderate physical activity was not associated with well-being. Higher levels of vigorous physical activity were associated with more positive affect [β(SE) = 0.307 (0.06), $p < 0.001$], to an estimated vigorous physical activity turning point [Point(95%CI) = 36.48 min/day (31.39–41.59)]. Similarly, higher levels of vigorous physical activity were associated with less negative affect [β(SE) = −0.250 (0.06), $p < 0.001$] up to the estimated vigorous physical activity turning point [Point (95%CI) = 37.35 min/day (31.27–43.44)]. The negative association between vigorous physical activity and negative affect was more pronounced in females than in males. Our findings highlight the importance of adolescents engaging in vigorous physical activity to improve positive affect and reduce negative affect.

1. Introduction

The physical, mental and cognitive health benefits of engaging in physical activity for young people are well documented (Janssen and LeBlanc, 2010). To gain these benefits, international physical activity guidelines recommend children (5–12 years) and adolescents (13–17 years) need to accrue at least 60 min of moderate-to-vigorous physical activity (MVPA) daily (World Health Organization, 2012). However, fewer than 20% of adolescents meet these targets (Rhodes et al., 2017). In 2012, the World Health Organization (WHO) Physical Activity Guidelines were revised to include recommendations for youth to engage in vigorous physical activity on three days each week (World Health Organization, 2012).

Emerging evidence indicates that vigorous intensity physical activity is more strongly associated with physical health outcomes in young people, compared to physical activity of light and moderate intensity (Gutin and Owens, 2011). For instance, a 7-year longitudinal study found vigorous physical activity (but not MVPA) to be inversely associated with BMI in a nationally representative sample of young people (n = 4770; aged 7 at baseline) (Hamer and Stamatakis, 2018). Furthermore, a cross-sectional study (n = 605; mean age 12.1 years) of objectively measured physical activity intensity and cardio-metabolic risk factors reported vigorous physical activity (but not light or moderate) was associated with reduced waist circumference, BMI-Z, systolic blood pressure, and improved cardiorespiratory fitness (Hay et al., 2012). While evidence suggests vigorous physical activity is important for physical health, less is known regarding the effect on mental health outcomes.

Mental health is not merely the absence of disease, the WHO broadly defines mental health as "*a state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution*

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to his or her community" (World Health Organization, 2004). It has been proposed that mental health can only be sufficiently represented when considering the interaction of both negative (e.g., ill-being, anxiety, depression, perceived stress) and positive (e.g., well-being, self-esteem, resilience) indicators (Masse et al., 1998). Of note, there is conceptual overlap among the different negative and positive indicators of mental health (Ryan and Deci, 2001). For the purpose of this paper, the term well-being will be used to reflect students' self-reported affect.

Review-level evidence suggests physical activity has the potential to improve aspects of adolescents' well-being. A review of reviews reported small-to-moderate positive effects of physical activity on self-esteem (Biddle and Asare, 2011), and a review by Lubans et al. (2012) found evidence to suggest that outdoor adventure programs can improve self-concept, resilience, perceptions of alienation and self-control (Lubans et al., 2012). However, much of the available evidence is derived from low quality studies and evidence relies heavily on self-reported physical activity. The few studies using objective measures of physical activity have typically involved small samples (Poitras et al., 2016), furthermore methodological challenges associated with use of different accelerometer cutpoints may impact consistency of findings (Cain et al., 2013). Most studies have explored linear relationships, however studies in other population groups suggest that this relationship may not be linear, and therefore other statistical methods such as quantile regression may be appropriate. For example, quantile regression has been used to examine the relationship between physical activity and obesity in youth aged 6–18 years (Mitchell et al., 2017) and the association between physical activity and teacher-reported academic performance in 9–10 year olds (Zhang et al., 2015). In addition to these methodological shortcomings, there is an absence of research specifically examining the relationship between physical activity intensity and affective well-being among adolescents (Parfitt et al., 2009).

To address these research gaps, our study aims to examine associations between physical activity intensity and hedonic well-being (i.e., positive and negative affect) in adolescents using quantile regression, exploring non-linear relationships. A secondary aim was to determine if associations are moderated by sex, as previous research has consistently documented that females engage in less physical activity than males (Belcher et al., 2010; Lagerberg, 2005), and suggests males and females may experience differential mental health effects (Kremers et al., 2007). Based on previous research (Biddle and Asare, 2011), we hypothesised that: (i) vigorous physical activity will be associated with well-being, (ii) light and moderate physical activity will not be associated with well-being, and (iii) the association between physical activity intensity and well-being will be moderated by sex.

2. Methods

Data from the 'Activity and Motivation in Physical Education (AMPED)' cluster RCT were examined in the current study. The full AMPED methodology is published elsewhere (Lonsdale et al., 2016). Briefly, students in Grade 8 from 14 government-funded secondary schools in Western Sydney (Australia) were recruited to participate in an intervention aiming to increase opportunities for physical activity in physical education (PE) and improve motivation for physical activity and PE. Data from three timepoints (baseline, 7–8 months, and 14–15 months follow-up) were combined to increase the sample size. Ethical approval were obtained from the Australian Catholic University (2014185N) and the New South Wales Department of Education (2013162).

2.1. Measures

Participants self-reported birthdate, sex, country of birth, language spoken at home and Indigenous origin. Socioeconomic status was measured using the Family Affluence Scale (Currie et al., 2008). Research assistants measured weight (recorded to the nearest 0.1 kg) and height (recorded to the nearest 0.1 cm), and body mass index (BMI) was calculated (weight(kg)/height (m)^2). BMI-z scores were calculated using the LMS (lambda-mu-sigma) method (Flegal and Cole, 2013).

2.2. Physical activity

Physical activity was assessed using ActiGraph accelerometers (GT1M, GT3X, GT3X+ models; Fort Walton Beach, FL). A range of device models were included as only vertical axis output were used for the current study, and other studies in adolescent populations have reported similar vertical axis outputs between devices (John et al., 2010). Study participants wore accelerometers for one week (five weekdays, two weekend days) at each timepoint (baseline, 7–8 months, 14–15 months), accelerometers were initialised to record data at 1 second epochs (Lonsdale et al., 2015). Consistent with other studies in adolescent populations (Cain et al., 2013), to be included in the analyses valid data defined as wear time of > 8 h on 3 days or more (including 2 weekdays) was required. Time (minutes/day) spent in physical activity of differing intensities (light (101–2295 cpm), moderate (2296–4011 cpm) and vigorous (> 4012 cpm)) was estimated, using validated cut-points (Evenson et al., 2008). Non-wear time, defined as ≥30 min of continuous '0' counts, was removed from the dataset (Carson et al., 2013).

2.3. Well-being

Well-being was assessed at each timepoint (baseline, 7–8 months, and 14–15 months follow-up) using the Positive and Negative Affect Scale (PANAS) for Children (Ebesutani et al., 2012). The PANAS is a self-report questionnaire using 10-item scales to measure positive and negative affect. Using a Likert scale of 1 (*not at all*) to 5 (*very much*), respondents rated each adjective according to the extent to which each describes the way they have felt during the 'past few weeks' (*positive affect*: joyful, cheerful, happy, lively, proud; *negative affect*: miserable, mad, afraid, scared, sad). Scores of the five-items were summed to create a total score out of 25 for each scale. Scores ranged from 5 to 25, higher positive affect scale scores representing higher positive affect, and lower negative affect scale scores representing reduced negative affect. Studies examining youth have found the PANAS to be a reliable and valid instrument to assess affect (Laurent et al., 1999).

2.4. Data analysis

Statistical analyses were conducted using R software (R project version 3.5.1). Summary statistics described variables of interest. Significance levels were set at $p < 0.05$. Participants who provided physical activity and affect data from at least one timepoint were included in the analysis. Polynomial (quadratic) mixed models were used to capture the potentially non-linear relationships between physical activity of light, moderate and vigorous intensity and positive and negative affect. An individual-level random term was also added to the models in order to account for the potential individual variability. When a quadratic effect was detected, a series of sensitivity checks were performed. The turning point of each curve and its 95% confidence interval (CI) was calculated using the Delta Method (Francq and Cartiaux, 2016). This approach has been used before in similar studies (Owen et al., 2018). Potential moderation effects (sex) were tested by including an interaction term in the equations. Lastly, quantile regressions were used in order to capture the potential differences in the impact that physical activity can have across the positive and negative affect distribution (we tested the orthogonal polynomial relationship at the 25th, 50th, 75th and 90th percentiles) in the study sample. All models were adjusted for sex, BMI-z score, ethnicity, wear-time, and other physical activity intensities (light, moderate, vigorous). Standardized regression coefficients of 0.1, 0.3 and 0.5 were considered small, moderate and large, respectively (Cohen, 1992).

Table 1
Baseline characteristics of sample (n = 1223).

Age in years (mean(SD))	12.94 (0.54)
Sex (%)	
Male	55.1%
Female	44.9%
Body mass index (BMI) (mean(sd))	22.68 (4.99)
Physical activity intensity (mean(sd))	
Total light PA (min/day)	81.51 (27.21)
Total moderate PA (min/day)	27.95 (11.07)
Total vigorous PA (min/day)	18.56 (10.91)
Daily accelerometer wear time (min/day) (mean(sd))	709.94 (120.38)
Affect (mean(sd))	
Positive affect (0–25)	18.05 (4.52)
Negative affect (0–25)	9.33 (4.09)

3. Results

3.1. Baseline participant characteristics

Briefly, the study sample included 1223 adolescents providing 3140 observations across three timepoints. At baseline the sample was 55.1% male and mean age of 12.94(0.54) years. The sample included 50% classified as 'normal weight' (mean BMI: 22.15(4.89)). Mean accelerometer wear time across the three timepoints was 709.94(120.38) minutes per day, including 81.51(27.21), 27.95(11.07) and 18.56(10.91) minutes of daily light, moderate and vigorous physical activity, respectively. Mean scores of 18.05(4.52) and 9.33(4.09) were recorded for positive and negative affect, respectively (Tables 1 and 2).

3.2. Positive affect and physical activity

There were no linear or quadratic relationships detected between light or moderate intensity physical activity and positive affect. Fig. 1 shows the curvilinear relationship between vigorous physical activity and positive affect in the study sample. Increasing levels of vigorous physical activity had a positive and moderate association with positive affect [β(SE) = 0.307 (0.06), $p < 0.001$] to the estimated vigorous physical activity turning point [Point(95%CI) = 36.48 min/day (31.39–41.59)], after which positive affect levels were lower with increasing levels of vigorous physical activity [β(SE) = −0.210 (0.053), $p < 0.001$]. Of the 3140 observations, 8.56% included a vigorous physical activity volume above this turning point. Sensitivity analyses showed sex had no effect on this curvilinear relationship (Fig. 2). The curvilinear relationship between vigorous physical activity and positive affect was consistent across the entire spectrum of positive affect levels (Fig. 3).

3.3. Negative affect and physical activity

There were no linear or quadratic relationships detected between light or moderate intensity physical activity and negative affect. As shown in Fig. 1, a curvilinear relationship existed, vigorous physical activity had a moderate and negative association with negative affect [β(SE) = −0.3 (0.06), $p < 0.001$] up to the estimated vigorous physical activity turning point [Point(95%CI) = 37.35 min/day (31.27–43.44)], after which negative affect levels were higher [β(SE) = 0.184(0.05), $p = 0.002$]. Of the 3140 observations, 7.73% included vigorous physical activity volume above this turning point.

Sex sensitivity analysis showed for the decreasing part of the curve ($p = 0.03$) the association between vigorous physical activity and negative affect was more pronounced in females than males (β(SE) = −0.038(0.02); however, no sex effect was detected for the increasing part of the curve (Fig. 2). This means that females appeared to benefit more from vigorous physical activity up to the turning point, but showed similar negative affect as males when engaging in very high levels of vigorous physical activity. Quantile regression analysis suggested that the curvilinear relationship between vigorous physical activity and negative affect was statistically significant for the 25th, 50th, and 75th percentiles but not for the 90th percentile of negative affect (Fig. 3), and that regression coefficients for the quantile 90th was statistically significant different from the other quantiles ($p < 0.05$).

Table 2
Mean time spent in physical activity of differing intensities at each study timepoint.

	Timepoint 1 (n = 1223) Minutes per day Mean (sd)	Timepoint 2 (n = 1087) Minutes per day Mean (sd)	Timepoint 3 (n = 830) Minutes per day Mean (sd)
VPA	18.56 (10.91)	19 (12.16)	18.45 (12.94)
MPA	27.95 (11.07)	28.33 (13.15)	27.86 (12.48)
LPA	81.51 (27.21)	77.42 (29.89)	74.37 (27.66)

4. Discussion

This study examined associations between physical activity intensity and well-being (positive and negative affect) in a large sample of Australian adolescents. Light and moderate physical activity was not associated with well-being. A favourable moderate association was observed between vigorous physical activity and more positive affect, to a turning point of ~36 min after which less positive affect was observed. When examining negative affect, engaging in up to ~37 min of vigorous physical activity was associated with less negative affect. The association between vigorous physical activity and negative affect was more pronounced in females than in males. Our study findings provide evidence for the benefits of engaging in vigorous physical activity (Tables 3 and 4).

4.1. Positive affect

In the current study, no associations between light or moderate intensity physical activity and affect were evident, however a curvilinear relationship between vigorous physical activity and positive affect was observed. Engaging in up to ~36 min/day of vigorous physical activity was associated with more positive affect. To our knowledge, there is an abundance of reviews examining associations between physical activity and various mental health outcomes (Biddle and Asare, 2011; Spruit et al., 2016; Wu et al., 2017), however there does not currently appear to be a review or meta-analysis specifically investigating the effect of physical activity on well-being outcomes in adolescents. While available evidence suggests physical activity to be beneficial for adolescent's self-esteem (Biddle and Asare, 2011), self-concept (Lubans et al., 2012; Spruit et al., 2016), externalizing problems and internalizing problems (Spruit et al., 2016), and health-related quality of life (Wu et al., 2017), the effect of physical activity intensity has scarcely been reviewed. Of note, emerging evidence suggests vigorous physical activity in the form of high intensity interval training (HIIT) has both short- and long-term benefits for adolescents' mental health, specifically after an 8-week HIIT trial small intervention effects were observed for well-being outcomes (Costigan et al., 2016).

4.2. Negative affect

In the current study, high levels of vigorous physical activity were associated with less negative affect, until the turning point of ~37 min after which more negative affect was observed. To date, most studies investigating associations between physical activity and well-being have been cross-sectional, and have reported mixed findings. For example, Goldfield et al. (2011) reported a significant reduction in depressive symptoms in males and anxiety for females (n = 1259; age:14.8 ± 1.8) who self-reported engaging in greater amounts of

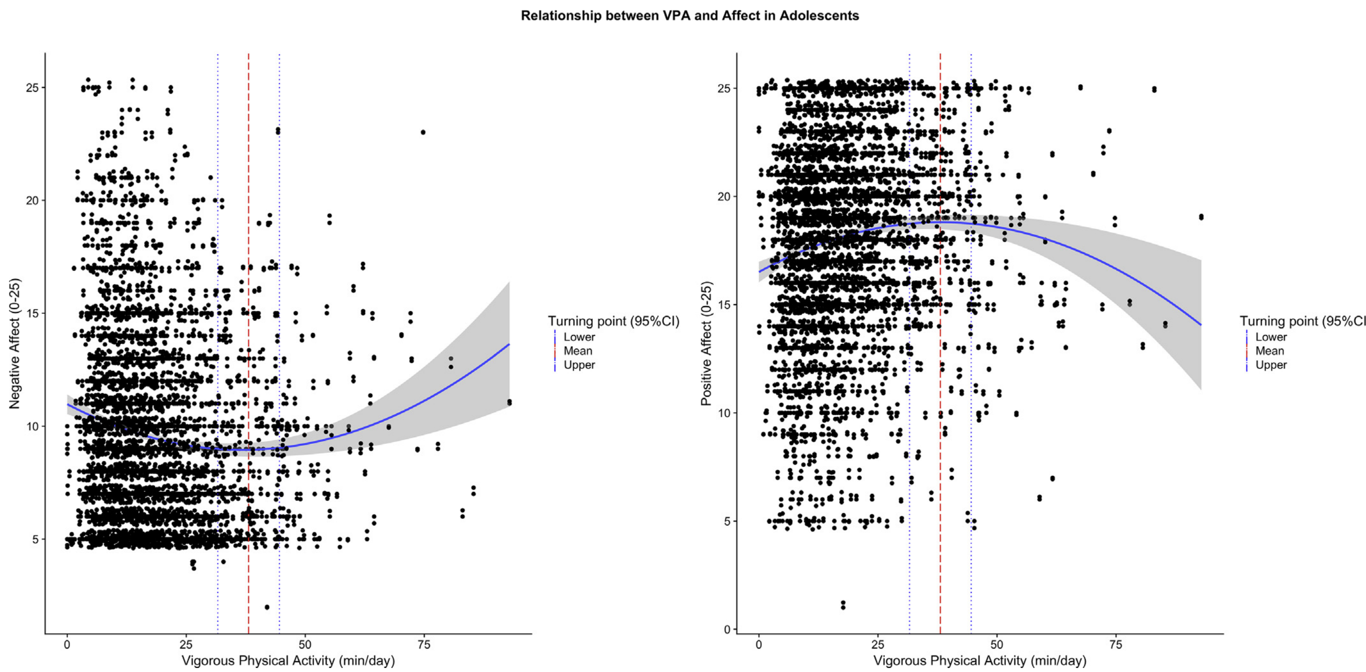

Fig. 1. Relationship between vigorous physical activity and affect in adolescents.

vigorous physical activity (defined as number of times/week engaging in vigorous physical activity for > 15 min/day) (Goldfield et al., 2011). However, other cross-sectional studies have found no association between vigorous physical activity and depression or anxiety (Allison et al., 2005), likewise in baseline data from the Trial of Activity for Adolescent Girls (n = 1397 girls; 12 age) no significant associations between depressive symptoms and physical activity intensity were observed (Johnson et al., 2008). Mixed findings may be attributed to differences in physical activity measurement for example self-report, small sample sizes in some studies and analysis approached utilised (e.g., the majority of studies have explored linear relationships, however relationships may not be linear across the distribution of the x variable).

4.3. Vigorous physical activity turning point

In the current study, a curvilinear relationship between time spent in vigorous physical activity and affect was observed. Interestingly, in a small number of cases (~7% for positive affect and ~8% for negative affect), engaging in higher amounts of vigorous activity was associated with less positive affect (i.e., > 36 min/day) and more negative affect (i.e., > 37 min/day). While engaging in regular physical activity has been shown as beneficial for adolescent health and well-being (Poitras et al., 2016), the ‘extreme exercise hypothesis’ (Eijsvogels et al., 2018) suggests when performed excessively or for extended periods (i.e., beyond optimal dose), exercise can adversely effect health. Previous studies indicate that those engaging in excessive levels of physical activity (e.g., elite athletes) can suffer from a range of other factors, including over-training, injury, stress, and pressure to perform (Armstrong and Vanheest, 2002), which may contribute to poor physical (Eijsvogels et al., 2018) and mental health outcomes. Furthermore, the curvilinear relationship between vigorous physical activity and negative affect was statistically significant for the 25th, 50th, and 75th percentiles, however not for the 90th percentile. It is likely that multiple factors contribute to these findings, for instance those reporting high negative affect may be experiencing other co-occurring conditions, adolescents participating in greatest vigorous physical activity (e.g., elite athletes) were experiencing poor mental health, or the environment, activities and/or social conditions may not be conducive to lowering negative affect (Rhodes and Kates, 2015). Longitudinal evidence is needed to assess the temporal sequence.

4.4. Potential mechanisms responsible for the effect of physical activity on mental health

A range of neurobiological, psychosocial and behavioural mechanisms might explain the relationship between intensity and well-being. Intense physical activity is likely to cause a release of endorphins which may result in changes to affect. Indeed, the ‘endorphin hypothesis’ proposes a reduction in depression and anxiety due to endogenous opioid peptide secretions released in the brain (Dishman and O'Connor, 2009). Adult studies have highlighted the potential role of endocannabinoids in producing exercise-induced improvements in affect, well-being, anxiety, post-exercise calm and pain sensation (Dietrich and McDaniel, 2004). Interestingly, the neurobiological effects of exercise appear to exhibit a ‘u-shaped’ curve, whereby moderate intensity physical activity resulted in greatest mental health effects, while highest and lowest intensity physical activity yielded limited effects (Raichlen et al., 2013).

A number of psychosocial mechanisms may also explain the positive association of physical activity on well-being, including social interaction, mastery in the physical domain, and improvements to appearance/self-perceptions (Morgan et al., 2016). While there is a lack of research examining such underlying mechanisms for adolescent populations, participation in physical activity programs that involve bouts of vigorous physical activity have the potential to improve adolescents' well-being via changes in fitness and body shape, improved self-efficacy and physical self-concept. Notably, a review of the psychological and social benefits of sport participation found adolescents participating in sport scored higher for psychological domains of well-being (Eime et al., 2013). The ‘social interaction hypothesis’ posits that interactions and mutual support gained via participating in physical activity together (North et al., 1990), and may explain the beneficial effects of vigorous physical activity on well-being. It has been hypothesised that changes in well-being associated with physical activity may be mediated by behavioural mechanisms such as improved sleep, coping skills and self-regulation (Morgan et al., 2016).

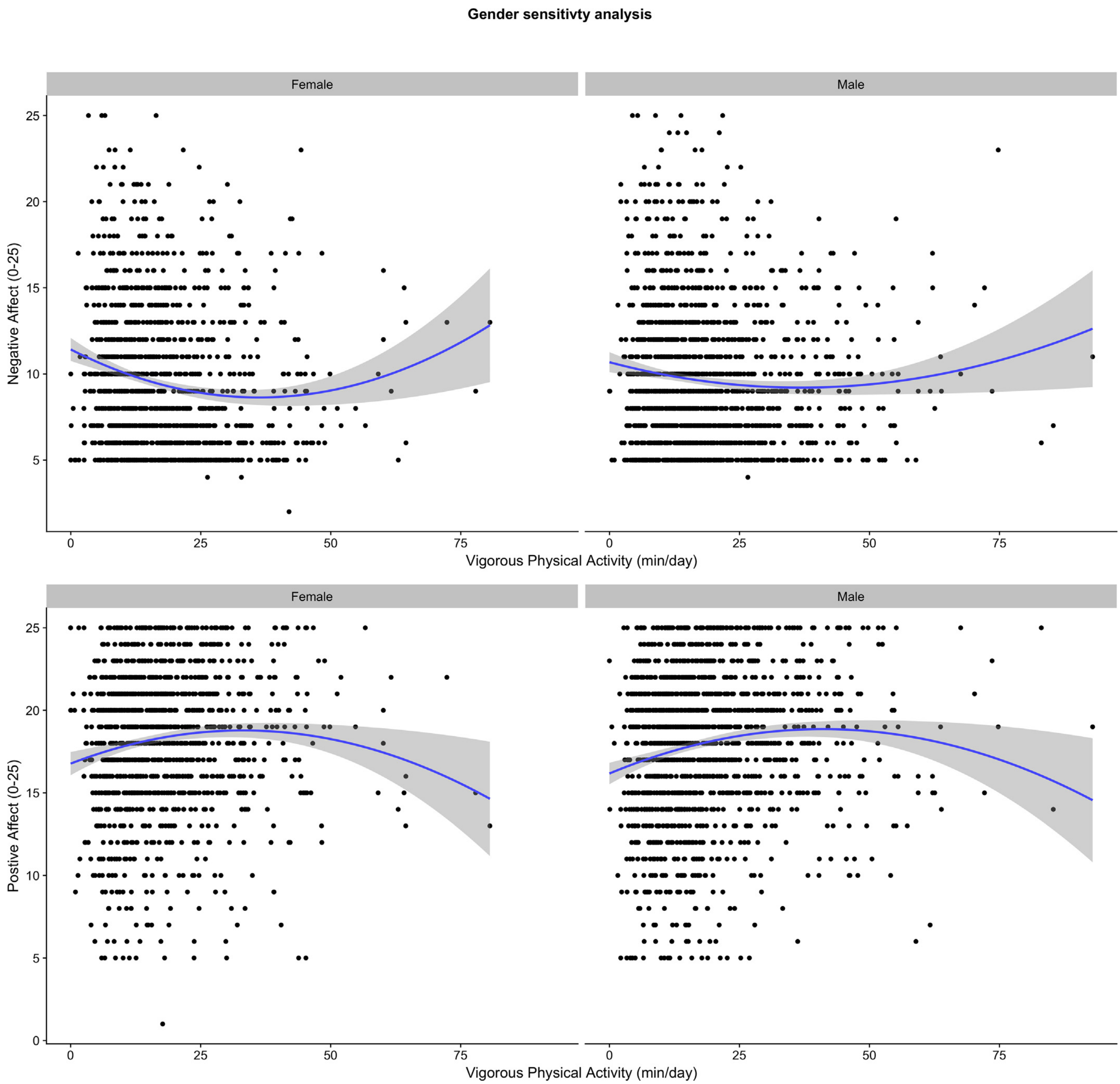

Fig. 2. Sex sensitivity analysis.

4.5. Moderators

Sex was a moderator of the association between vigorous physical activity and negative affect. Females appeared to benefit most from engaging in vigorous intensity physical activity (i.e., higher vigorous physical activity was associated with less negative affect) up to the turning point. Previous research suggests sex may be a key factor moderating associations between physical activity and well-being (Kremers et al., 2007). A more pronounced reduction in negative affect for females might be explained by existing higher negative affect scores compared to males (PANAS negative affect baseline score: 10 vs. 9.2, $p < 0.05$) and lower levels of vigorous physical activity reported by females compared to males (14.7 min/day vs. 22.03 min/day, $p < 0.05$). Sex differences in physical activity levels are consistently documented, with females engaging in less physical activity than males (Belcher et al., 2010; Lagerberg, 2005), this trend continues when specifically examining vigorous physical activity participation (Parfitt et al., 2009). Alternatively, physical activity may yield other improvements for females (e.g., self-esteem, self-concept and appearance), which also contribute to less negative affect and more positive affect. Strategies tailored specifically according to sex, which promote relevant opportunities (e.g., activity type, delivery methods) to engage in more vigorous physical activity, appear needed for inactive girls. The importance of targeted and tailored physical activity interventions for enhancing well-being, which reflect sex differences, has been previously highlighted (Morgan et al., 2016).

4.6. Strengths and limitations

This study addresses gaps highlighted in existing literature and has a number of strengths. Firstly, the use of objectively measured physical activity using accelerometry is a strength, as much of the existing

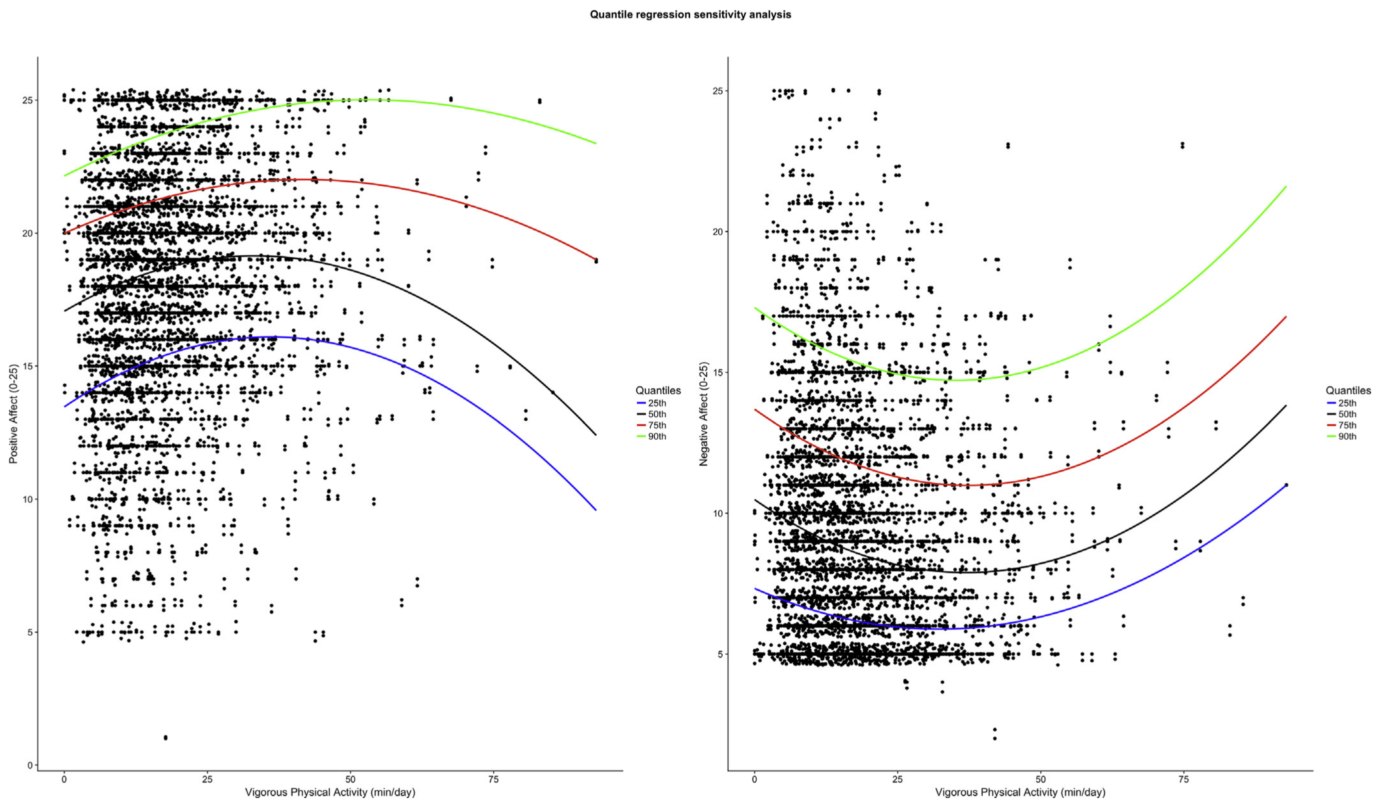

Fig. 3. Quartile regression sensitivity analysis.

literature is based on self-reported physical activity. Secondly, this study examined associations between affect and time spent in physical activity of differing intensities (light, moderate, vigorous). Finally, the large number of observations included in the analyses is a strength, previous literature has commonly included small samples. However, study limitations should also be acknowledged. The cross-sectional design of this study limits causal inferences, future experimental studies are encouraged to further investigate associations. The sample is not representative of the wider population which limits generalizability of the study findings. Furthermore, affect is just one component of well-being and a range of components, including indicators of eudemonic wellbeing (e.g., life satisfaction) should be tested in the future to provide a more robust indication of changes in this aspect of mental health.

4.7. Conclusions and future direction

The evidence from this study adds to the current body of knowledge documenting the potential benefits of vigorous physical activity for adolescents' well-being. More time spent in vigorous physical activity was associated with improved affective well-being. However, for a small number of adolescents extended vigorous intensity physical activity may heighten negative affect and lessen positive affect. Females appear to benefit most from engaging in vigorous physical activity, which may be explained by lower vigorous physical activity levels and higher negative affect reported. While participation in any physical activity should be supported, the current study highlights the importance of encouraging adolescents to participate in bouts of vigorous intensity physical activity for enhanced affective wellbeing. Our findings help to provide evidence for necessary vigorous physical activity accrual for adolescents, as recommended on 3 days per week in the current physical activity guidelines.

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The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation, and do not constitute endorsement by ACSM.

Table 3
Estimates (β and Std. Error) of the association between positive and negative affect with physical activity intensity in the study sample.

Predictors (Fixed-effects)	Positive affect			Negative affect		
	Un-standardized coefficients	*p* value	Standardized coefficients	Un-standardized coefficients	*p* value	Standardized coefficients
LPA (min/day)	0.047	0.274	0.300	0.001	0.837	0.010
LPA^2 (min/day)	−0.000	0.262	−0.269	−0.000	0.197	−0.053
Mod (min/day)	−0.008	0.651	−0.0232	0.027	0.127	0.078
Mod^2 (min/day)	−0.000	0.052	−0.096	−0.000	0.399	−0.037
Vig (min/day)	0.115	< 0.001	0.307	−0.088	< 0.001	−0.300
Vig^2 (min/day)	−0.001	< 0.001	−0.209	0.001	< 0.001	0.184

All models were further controlled for age, BMI-z score at baseline, wear time, and each other physical activity intensity.

Table 4
Curvilinear effect of vigorous physical activity on well-being at different percentiles of the outcome (well-being) distribution.

	Beta coefficient (linear/quadratic)			
	25th percentile	50th percentile	75th percentile	90th percentile
Positive affect	0.128/−0.001*	0.120/−0.001*	0.080/−0.000*	0.104/−0.000*
Negative affect	−0.080/0.001*	−0.108/0.001*	−0.102/0.001*	−0.081/0.001

* $p < 0.05$.

Declaration of competing interest

No potential conflict of interest was reported by the authors.

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