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ABSTRACT

Background: Physical activity and sedentary behavior may differentially impact health-related quality of life in adults with cerebral palsy. **Objective:** The present investigation assessed the independent relationships between aspects of physical activity and sedentary behavior related to health related quality of life in adults with cerebral palsy. **Methods:** Through a cross-sectional online survey of 118 adults with cerebral palsy, participants self-reported the extent of their functional impairments using the Gross Motor Function Classification System, Manual Ability Classification System, and Communication Function Classification System; while mental and physical health-related quality of life were assessed using the RAND-36. Physical activity and sedentary behavior were quantified using the Physical Activity and Disability Survey—Revised and Sedentary Behavior Questionnaire, respectively. **Results:** Accounting for potential confounding influences of impairments, neither exercise-related physical activity, leisure time- related physical activity, occupational physical activity, nor sedentary behavior was associated with any characterization of health-related quality of life. However, greater engagement in general lifestyle physical activity was related to superior mental health-related quality of life. **Conclusion:** These findings provide initial evidence to suggest that focusing public health and therapeutic recommendations for individuals with cerebral palsy on general physical activity engagement throughout the day might incur potential benefits for enhancing mental health- related quality of life in this population.

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Exercise; functional impairment; health-related quality of life; physical activity

Stemming from the modern tendency for individuals to participate in sedentary activities, both the American (2018 Physical Activity Guidelines Advisory Committee, 2018) and Canadian (ParticipACTION, 2018) physical activity directives emphasize the importance of engaging in physically activity behaviors—and avoiding sedentary behavior—not only for physical health, but also for mental health. While these directives make broad recommendations across the life span, a paucity of research has examined such relationships in those with disabilities, particularly in those with movement-related disorders. However, individuals with movement disorders such as cerebral palsy generally report less frequent engagement in physical activity behaviors than do other populations, with fewer than 10% of individuals with cerebral palsy meeting physical activity recommendations (Maher et al., 2007; van Eck et al., 2008; Zwier et al., 2010). As cerebral palsy is one of the most common movement-related disabilities (Odding et al., 2006; Rosenbaum et al., 2007), understanding the interrelationships between physical activity (and its related constructs such as sedentary behavior) and mental health in this population is vital to support public health recommendations and the development of therapeutic recommendations. Accordingly, the present investigation aimed to assess the independent relationships between aspects of physical activity and sedentary behavior related to health-related quality of life in adults with cerebral palsy.

Cerebral palsy refers to neurodevelopmental disability encompassing an array of disorders attributed to nonprogressive disturbances occurring within early development

(Rosenbaum et al., 2007). To create environments where individuals with cerebral palsy can thrive, it is imperative that we understand those factors that best optimize health-related quality of life, which will influence how we offer physical activity opportunities to address the 75% of children and adolescents with ambulatory cerebral palsy who fail to meet physical activity recommendations—engaging in less than 60 minutes of moderate-to-vigorous physical activity each day (Mitchell et al., 2015). Yet, there may be a bidirectional relationship between physical activity and symptom severity. Individuals with the most extensive levels of spastic paresis and mobility impairments are less likely to engage in skeletal muscle-induced bodily movement (i.e., physical activities).

However, current physical activity directives note that while physical activity and sedentary behavior are inversely related, they represent different constructs and potentially independent risk profiles (2018 Physical Activity Guidelines Advisory Committee, 2018). Specifically, from an independent construct perspective, sedentary behavior is operationalized not as an endpoint of the physical activity continuum, but as the engagement in prolonged inactive wakeful behaviors while in a sitting or reclining position. Even within the broad classification of physical activity, the construct of exercise-related physical activities represents a substantively different construct than leisure time activity, general lifestyle-related activity, and occupational activities (Caspersen et al., 1985). As such, the focus on characterizing the influence of only physical activity behaviors broadly construed on symptomatology associated with

cerebral palsy provides limited insight into the potential therapeutic benefits of engaging in physical health behaviors.

Of particular interest is that while impairments resulting from cerebral palsy have the potential to adversely impact the individuals' quality of life—particularly as they progress into adulthood (Calley et al., 2012; Zaffuto-Sforza, 2005), physical activity may be a protective behavior. Indeed, within the growing body of research investigating the benefits of physical activity for individuals with cerebral palsy, a number of investigations have assessed the benefits of physical activity as they relate to the construct of health-related quality of life (Alves-Nogueira et al., 2020). The overarching concept of quality of life is a subjective and multidimensional construct that broadly encompasses an individual's self-valuations and perceptions related to their life satisfaction (Whoqol Group, 1994), with the concept of health-related quality of life specifically reflecting an individual's self-valuations and perceptions related to their well-being (Karimi & Brazier, 2016). Although there remains debate as to how exactly to define health-related quality of life and differentiate it from other related constructs (Alves-Nogueira et al., 2020; Karimi & Brazier, 2016), a consistent finding across typical/able-bodied preadolescent, adolescent, and adult populations has been that physical activity is associated with superior health-related quality of life (Bize et al., 2007; Marker et al., 2018). Preliminary findings within individuals with cerebral palsy have similarly observed greater health-related quality of life in association with higher levels of physical activity (Gaskin & Morris, 2008). Specifically, in a sample of 51 adults with cerebral palsy, Gaskin and Morris (2008) observed that greater time spent in household physical activities was correlated with the physical functioning component of health-related quality of life, with no significant relationships observed with exercise-related physical activity.

However, a key limitation of the extant literature in this area is that studies either employed small sample sizes or failed to account for the potential confounding influence of functional impairments, which themselves have been demonstrated to be inversely related with health-related quality of life (Morgan et al., 2014; Tarsuslu & Livanelioglu, 2010). Similarly, there remains an open question regarding how various aspects of physical activity (e.g., exercise-related physical activity, leisure time-related physical activity, general physical activity (i.e., activities of daily living), and occupational/school-related physical activity) as well as sedentary behavior may be associated with health-related quality of life. Accordingly, utilizing a well-powered hierarchical regression approach accounting for potential confounding factors, the present investigation sought to better characterize how the quality of life in adults with cerebral palsy was related to the independent constructs of exercise-related physical activity, leisure time physical activity, general physical activity, occupational physical activity, and sedentary behavior.

Method

Participants

Individuals with self-reported cerebral palsy were recruited to participate through e-mail, social media, and a podcast

about life for adults with cerebral palsy. Of the 220 initially expressing interest, 157 individuals provided written informed consent in accordance with the policies of the Michigan State University Human Research Protection Program Institutional Review Board, which are consistent with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Of the individuals consenting to participate, 148 individuals initiated the online survey. Analyses were conducted on a final sample of 118 participants (84 female; 38.4 ± 11.4 years of age) who completed the online survey. Demographic characteristics are provided in Table 1. Although the extent of impairment associated with cerebral palsy was relatively consistent with the extant literature, as the sample constitutes a predominantly white, hemiplegic, overweight based on BMI, and inactive population some caution is warranted in regard to the overall generalizability of the present investigation to the broader literature.

Procedure

Using a cross-sectional design, participants completed all assessments online (pre-Covid19). After following a general participation link, interested participants were provided with a description of the study and informed consent documentation, including an explanation of their rights as participants. Following consenting to participate, participants were asked to complete a basic demographic questionnaire; the Physical Activity and Disability Survey—Revised (Kayes et al., 2009) assessing lifestyle exercise-related physical activity and general physical activity levels; and the Sedentary Behavior Questionnaire (Rosenberg et al., 2010) to assess lifestyle sedentary behavior. Additionally, participants were asked to complete the RAND 36-item health survey (Hays et al., 1993) to assess

Table 1. Mean ($\pm$ SD) values for demographic attributes, physical activity, sedentary behavior, symptoms, and quality of life variables.

Measure	Mean ($\pm$ SD)
N	118 (84 female)
Age (years)	38.4 ± 11.4
Education	69.5% with College or Vocational Degree
Race	11% Nonwhite
Cohabitation	26.3% Live alone
Topography	
Monoplegia	11.0%
Diplegia	1.7%
Hemiplegia	55.1%
Triplegia	17.8%
Quadriplegia	14.4%
Mobility Assistance	
Unreported	59.3%
Leg Braces, Walker, Cane, or Crutches	10.1%
Wheelchair	9.3%
Power Chair	21.2%
Body Mass Index	27.3 ± 7.2
Exercise-Related Physical Activity (z score)	-0.4 ± 1.2
Leisure Time-Related Physical Activity (z score)	-1.5 ± 1.0
General Physical Activity (z score)	-1.2 ± 0.9
Occupational Physical Activity (z score)	1.1 ± 1.8
Lifestyle Sedentary Behavior (hours per week)	66.3 ± 28.0
Mental Health-Related Quality of Life (t score)	50.2 ± 8.3
Physical Health-Related Quality of Life (t score)	49.9 ± 7.4

mental and physical health-related quality of life, and to self-report their cerebral palsy symptoms using the gross motor function classification system (Palisano et al., 1997), the manual ability classification system (Eliasson et al., 2006), and the communication function classification system (Hidecker et al., 2011). All measures were administered online using Qualtrics Survey Software (Qualtrics, Provo, UT). Participation in this investigation was entirely voluntary and no compensation was provided for participants' engagement with this study.

Extent of impairment

This study used the Gross Motor Function Classification System (GMFCS) to quantify mobility-based gross motor functions (Palisano et al., 1997). The ability to use upper extremities, complete daily tasks, and manipulate objects was quantified using the Manual Ability Classification System (MACS) (Eliasson et al., 2006). Finally, the Communication Function Classification System (CFCFS) was used to quantify the ability to communicate with others (Hidecker et al., 2011). Each of these systems classified function on a scale of 1 to 5, with level 5 reflecting the most assistance required and level 1 being the most independent. Each of the disability classifications was self-determined, with participants selecting a description of ability that most related to them. Impairment characteristics are provided in Table 2.

Physical activity and sedentary behavior

Physical activity was measured using the Physical Activity and Disability Survey—Revised (Kayes et al., 2009), which assesses physical activity behaviors across a variety of situations specific to individuals with mobility-related impairments with high test-retest reliability (0.92). The focus of the present investigation was specifically on exercise-related physical activity (i.e., activity with the primary purpose of maintaining or improving health and fitness), leisure time-related physical activity (i.e., sports, recreational, or leisure time activities), general physical activity (i.e., activities of daily living), and occupational/school-related physical activity (i.e., activity associated with work/school and transportation to work/school) subscales. Sedentary behavior was also assessed using the sedentary behavior questionnaire (Rosenberg et al., 2010), which asked participants to recall typical hours/day spent engaged in nine various sedentary behaviors (TV watching, lounging, computer use, etc.).

Table 2. Frequency counts for level of impairment on the GMFCS, MACS, and CFCFS scales.

Level	Gross Motor Function Classification System	Manual Ability Classification System	Communication Function Classification System
I	27 (22.9%)	38 (32.2%)	93 (78.8%)
II	47 (39.8%)	60 (50.8%)	17 (14.4%)
III	18 (15.3%)	16 (13.6%)	5 (4.2%)
IV	16 (13.6%)	3 (2.5%)	1 (0.8%)
V	10 (8.5%)	1 (0.8%)	2 (1.7%)

Quality of life

Quality of life was assessed using the RAND-36 (Hays et al., 1993). The RAND-36 has been previously used to assess quality of life for adults with disabilities and has been specifically used in adults with cerebral palsy (Gaskin & Morris, 2008). Given the nonunitary construct of health-related quality of life, the present investigation focused on the composite metrics of mental health-related quality of life and physical health-related quality of life. Mental health-related quality of life reflects an individual's emotional/social functioning, whereas physical health-related quality of life reflects physical health/functioning and limitations (Folsom et al., 2009).

Statistical analysis

Prior to analysis, all variables were screened for homoscedasticity and normality. For each analysis, variables of interest were assessed separately to ensure any findings were not biased due to multicollinearity. Within each variable of interest, an initial model characterized the influence of descriptive factors (Age, Biological Sex [0 = Female, 1 = Male], Race [0 = White, 1 = Nonwhite], Hispanic [0 = No, 1 = Yes], Education, Cohabitation [0 = No, 1 = Yes]) and level of impairment (GMFCS, MACS, CFCFS). Hierarchical linear regression analyses were then performed to determine the independent contributions of physical activity (exercise, leisure time, general, and occupational) and sedentary behavior for explaining variance in quality of life (mental and physical health-related quality of life), after accounting for descriptive factors and extent of impairment (Pontifex et al., 2014, 2016). Level of impairment was considered as a potential interactive factor; however, as all interaction terms failed to reach statistical significance, level of impairment was considered only as a covariate. Similarly, findings from the analysis remained consistent even when contrasting against a null model rather than accounting for descriptive factors and extent of impairment. All data analyses were performed in R Version 4.0 (R Core Team, 2019) with a familywise alpha level of $p = .05$ using the stats (R Core Team, 2019), fmsb (Nakazawa, 2019), psychometric (Fletcher, 2010), lm.beta (Behrendt, 2014), and Rmimic (Pontifex, 2020) packages. Effect sizes are reported as Cohen's f^2 . Exploratory analysis also considered biological sex and sedentary behavior as potential interactive factors. However, as all findings replicated the primary analysis, only the primary analysis is reported below.

Results

Of the participants completing the online survey, 55.1% reported having hemiplegia (paralysis on one side of the body) and 21.2% of participants reported requiring a power chair for mobility assistance. The racial and ethnic distribution of the sample was: 2 (1.7%) American Indian or Alaska Native, 7 (5.9%) Asian, 4 (3.4%) Black or African American, 101 (85.6%) White or Caucasian, with 4 (3.4%) individuals identifying as being of Hispanic origin. Demographic characteristics and mean values ($\pm$ SD) for variables of interest are provided in Table 1.

Preliminary analyses were conducted examining the correlations between physical activity behaviors assessed using the PADS-R survey as well as lifestyle sedentary behavior (see Table 3). Exercise-related physical activity exhibited a moderate relationship with leisure time physical activity ($r = 0.53$ [95% CI: 0.38 to 0.65], $p < .001$). A weak to moderate relationship was also observed between general physical activity and occupational physical activity behaviors ($r = 0.36$ [95% CI: 0.19 to 0.51], $p < .001$). Lifestyle sedentary behavior exhibited only a weak inverse relationship with general physical activity ($r = -0.25$ [95% CI: -0.42 to -0.08], $p = .006$). Summaries of the hierarchical regression analysis are provided in Table 4.

The relationship between physical activity/sedentary behavior and quality of life

Mental Health-Related Quality of Life: Hierarchical regression analysis indicated that general physical activity was associated with a statistically significant ($F_{change}(11, 106) = 4.7$, $p = .032$, $f^2 = 0.04$ [95% CI: 0.01 to 0.14]) change in variance in mental health-related quality of life such that greater general physical activity was associated with superior mental health-related quality of life ($R^2_{change} = 0.03$; see

Figure 1). Whereas, neither exercise, leisure time physical activity, occupational physical activity, or lifestyle sedentary behavior was associated with a statistically significant ($F_{change's}(11, 106) \leq 2.4$, $p's \geq 0.1$, $f^2's \leq 0.02$ [95% CI: 0.0 to 0.09]) change in variance in mental health-related quality of life ($R^2_{change's} \leq 0.02$).

Physical Health-Related Quality of Life: Hierarchical regression analysis indicated that neither exercise, leisure time physical activity, general physical activity, occupational physical activity, nor lifestyle sedentary behavior was associated with a statistically significant ($F_{change's}(11, 106) \leq 0.5$, $p's \geq 0.47$, $f^2's \leq 0.01$ [95% CI: 0.0 to 0.04]) change in variance in physical health-related quality of life ($R^2_{change's} \leq 0.01$; see Figure 2).

Discussion

The present investigation aimed to determine the independent relationships of separate constructs of physical activity and sedentary behavior with health-related quality of life in adults with cerebral palsy. The findings revealed that neither exercise-related physical activity, leisure time-related physical activity, occupational physical activity, nor sedentary behavior was associated with any characterization of health-related quality

Table 3. Correlations between physical activity- and sedentary behavior-related variables of interest.

	1.	2.	3.	4.	5.
1. Exercise- Related Physical Activity (z score)	–				
2. Leisure Time- Related Physical Activity (z score)	.526**	–			
3. General Physical Activity (z score)	.257*	.055	–		
4. Occupational Physical Activity (z score)	.223*	.149	.359**	–	
5. Lifestyle Sedentary Behavior (z score)	–.002	.132	–.254*	–.095	–

Note: *indicates $p \leq .05$. **indicates $p \leq .001$.

Table 4. Summary of the Hierarchical Regression Analysis.

	R ²	R ² change	B [95% CI]	SE B	β	t
Mental Health-Related Quality of Life						
Exercise-Related Physical Activity	0.26	0.02	0.98 [–0.27 to 2.23]	0.63	0.14	1.6
Leisure Time Physical Activity	0.24	<0.01	0.06 [–1.34 to 1.46]	0.71	0.01	0.1
General Physical Activity	0.27	0.03	2.00 [0.18 to 3.83]	0.92	0.23	2.2*
Occupational Physical Activity	0.25	<0.01	–0.28 [–1.12 to 0.55]	0.42	–0.06	0.7
Lifestyle Sedentary Behavior	0.25	0.01	–0.03 [–0.09 to 0.02]	0.03	–0.11	1.2
Physical Health-Related Quality of Life						
Exercise-Related Physical Activity	0.20	<0.01	0.18 [–0.98 to 1.34]	0.59	0.03	0.3
Leisure Time Physical Activity	0.20	<0.01	0.06 [–1.22 to 1.35]	0.65	0.01	0.1
General Physical Activity	0.20	<0.01	0.63 [–1.08 to 2.34]	0.86	0.08	0.7
Occupational Physical Activity	0.20	<0.01	0.26 [–0.51 to 1.03]	0.39	0.06	0.7
Lifestyle Sedentary Behavior	0.20	<0.01	–0.02 [–0.06 to 0.03]	0.02	–0.06	0.6

Note: *indicates $p \leq .05$. Models were assessed relative to an initial model characterizing the influence of descriptive factors (Age, Biological Sex [0 = Female, 1 = Male], Race [0 = White, 1 = Nonwhite], Hispanic [0 = No, 1 = Yes], Education, Cohabitation [0 = No, 1 = Yes]), and level of impairment (GMFCS, MACS, CFCS).

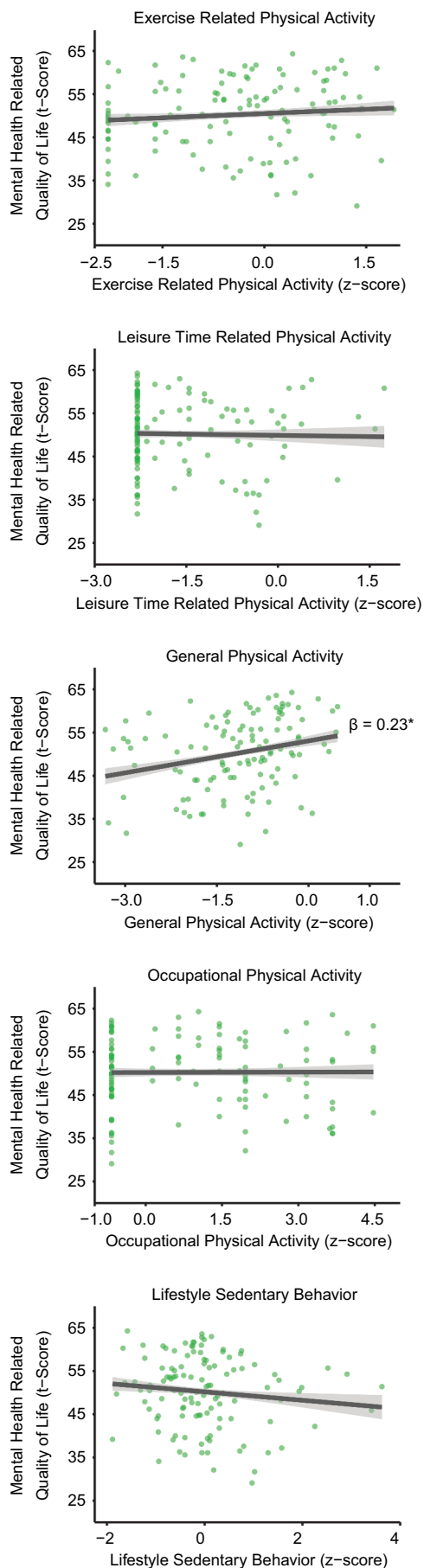


Figure 1. Scatterplots of the relationship between physical activity/sedentary behavior and mental health-related quality of life.

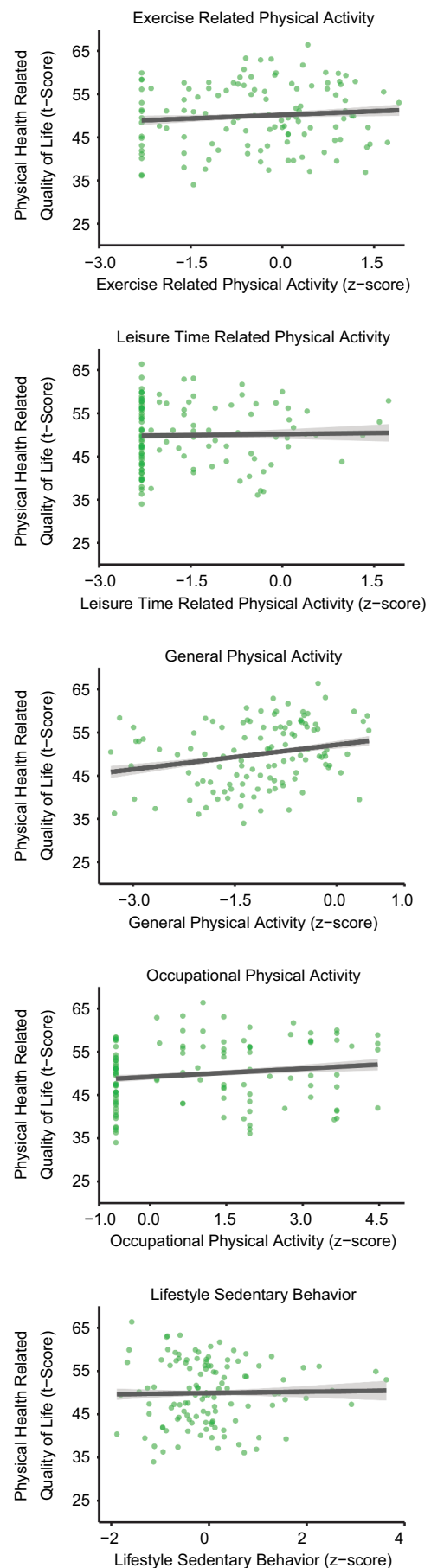


Figure 2. Scatterplots of the relationship between physical activity/sedentary behavior and physical health-related quality of life.

of life. Rather, general lifestyle physical activity behavior was observed to relate to superior mental health-related quality of life. However, general lifestyle physical activity behavior was not observed to relate to physical health-related quality of life in adults with cerebral palsy.

Consistent with a substantial body of prior research in able-bodied adults (Fox, 1999; Gill et al., 2013), general physical activity engagement was positively associated with mental health-related quality of life. Such findings contribute to the extant literature in this area, suggesting that emotional stability and well-being are positively related to general physical activity engagement expanding these findings to include adults with cerebral palsy. Within the present investigation, the overall model accounting for the influence of age, biological sex, race/ethnicity, education, cohabitation, and level of impairment, and general physical activity was observed to account for 27% of the variance in mental health-related quality of life. However, in contrast to the findings of Gaskin and Morris (2008), no relationship was observed between physical activity and physical health-related quality of life. Given the preliminary nature of their investigation—which utilized a small sample and assessed the correlations between individual scales of quality of life and physical activity (Gaskin & Morris, 2008)—such discrepant findings should be interpreted cautiously as the present investigation used composite scale metrics to more broadly assess the constructs of health-related quality of life.

Nevertheless, consistent with the findings of Gaskin and Morris (2008), neither exercise-related physical activity, leisure time physical activity, occupational physical activity, or sedentary behavior was observed to relate to aspects of quality of life. Although speculative, the lack of a relationship of physical health behaviors with physical health-related quality of life may be a manifestation of the relative stability of the physical limitations associated with cerebral palsy. As such, the construct of physical health-related quality of life may be substantially less malleable in adults with cerebral palsy than in other populations. Further, it is important to acknowledge that the engagement in physically active behaviors may also exacerbate awareness of limitations that load on to the construct of physical health related quality of life, potentially offsetting any benefits associated with physical activity participation. While the present investigation is well powered for this area of research, it may also be that the relationship of physical health behaviors with physical health-related quality of life is simply too small to be detected given the statistical power of the present investigation. Alternatively, it may be that the approach to measuring the construct of physical health-related quality of life is not sufficiently refined to capture potentially clinically relevant differences in this population. Future research should more carefully consider the particular alignment between aspects of physical health-related quality of life that may be relevant for individuals with cerebral palsy and the specific questions/prompts/methods of assessing such constructs. In doing so, future research may better capture those behaviors that optimize specific components of quality of life.

Given the cross-sectional research design employed within the present investigation, it is important to acknowledge that individuals with greater emotional stability and well-being may also have been able to engage in greater levels of general

physical activity. Thus, further research is necessary to better understand the directionality of these relationships and the extent to which they may exist within a positive feedback loop. Although the use of an online approach for data collection allowed for a broad range of participation well beyond geographically restricted limitations of in-person investigations, an additional limitation of the present investigation was the reliance on self-reported physical activity and sedentary behavior. Additional insight may also be provided through the assessment of 24-hour movement behaviors that could better capture habitual engagement in health related behaviors such as sleep, the avoidance of sedentary behavior, light physical activity and moderate to vigorous physical activity. Future research may benefit from the inclusion of more robust measures of these behaviors that could be facilitated through direct mailing of or use of multisensor wearable technology/algorithms, along with more comprehensive 24-hour movement perspectives.

Additionally, although the online approach enabled for a robust sample size (Alves-Nogueira et al., 2020), this approach may have been a barrier for those with more severe impairments associated with cerebral palsy, despite the disability-friendly features of the Qualtrics survey software. As such, there may be additional benefit for integration of semistructured interviews, and mixed-method analysis to better capture the wide range of potential behaviors associated with physical activity and sedentary behavior that might provide a more nuanced relationship with aspects of quality of life. Such an approach may also enable assessment of a more generalizable sample. Finally, as the design of the present investigation had no way of ensuring that individuals who completed the online survey were not engaging in intentional false reporting or other malfeasant behavior, some caution is warranted in not overinterpreting the findings of the present investigation. However, as the surveys took approximately 15 minutes to complete (with some participants taking in excess of 40 minutes), the effort required to intentionally bias the study presents as a potential barrier to such behaviors. Given that the findings largely replicate and extend the existent literature, at the very least the present investigation provides initial information from which future investigations can draw to advance this literature base.

Collectively, then, findings from this investigation provide initial evidence that public health and therapeutic recommendations directed toward individuals with cerebral palsy should particularly focus on general physical activity engagement throughout the day, rather than exercise/leisure time/occupational-related activities or just the avoidance of sedentary behavior. Such a focus might be particularly advantageous in this population, not only in regard to the potential benefits for enhancing mental health-related quality of life, but also as it relates to perceptions of feasibility. Speculatively, given the physical impairments and spastic movements of individuals with cerebral palsy, recommendations centered on generally being more active may be interpreted as a more achievable goal. The efficacy and tolerability of such recommendations, then, may enhance the adoption of the recommended behaviors associated

with engagement in more moderate to vigorous physical activity. However, clearly further research utilizing longitudinal approaches is necessary to better examine the extent to which increasing general levels of physical activity are effective at enhancing mental health-related quality of life.

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