Paediatric physical activity and health: Moving towards a measure of quality

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REVIEW

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A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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abstract

It is clear that physical activity, holistically, is linked with several positive factors through the life course. There exists a large evidence base for physical activity quantity, yet there has been little integration of physical activity qualities, and whilst *quality* is a nebulous term, recent developments in literature suggest it may be a viable measure in the characterisation of physical activity. The purpose of the study was to comprehensively review the development towards a measure of physical activity quality.

A review of literature was conducted using online databases: Web of Science, PubMed and Google Scholar. A narrative review was subsequently prepared on the topic and development of physical activity quality.

Quantitative assessment of movement quality shows promise in the evaluation and measurement of physical activity, particularly in relation to motor development, fundamental movement skills and body mass indices.

Whilst measures of movement quality display promise, this is a burgeoning field of research contributing to physical activity literature, and as such, these measures must be refined, developed and investigated further.

Key words: physical activity, movement quality, health, children.

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INTRODUCTION

Physical inactivity is the largest contributor to risk factors for non-communicable diseases in the world [1–3]. Conversely, physical activity has been identified as an integral contributor to a healthy lifestyle [4] and can provide numerous health benefits [5], including a decreased risk of premature death by around 30% for those attaining the recommended levels of physical activity on most days of the week (see [1,2]). Whilst this data is not available for children, the systematic reviews of Saunders et al. [6], Chaput et al. [7], Carson et al. [8] and Poitras et al. [9] have quantified the relationship between physical activity, sedentary behaviour, sleep and health and concluded that these behaviours are co-dependent and all related to health risk [10]. A sedentary lifestyle, common during childhood, adolescence and continued into adulthood, is a major concern for the health of the general public [11, 2], and the substantial increase in the prevalence of overweight and obesity and other non-communicable diseases, such as diabetes, cancer, hypertension and cardiovascular diseases over the previous decades [12, 13], is partly attributed to lower levels of physical activity and an increase in sedentary behaviour [14]. There are numerous acute physiological and psychosocial benefits of physical activity among children and adolescents; physical activity behaviours between childhood and adulthood are correlated, and physically active children are more likely to grow up to be physically active adults compared with their inactive peers [15, 16]. It is, therefore, advocated that physical activity be promoted amongst children and adolescents for health enhancement and to embed lifelong behavioural patterns that will result in more active adult populations in the future [10, 15–17].

There is a dearth of research demonstrating objective methods to empirically derive movement quality measures, and as such, this review intends to explore the development towards novel measures of movement quality. Authors, such as Bellanca et al. [18] and Brach et al. [19], have demonstrated quality measurements in a specific population are useful and valid using raw accelerometry, enabling greater insight into specific portions of gait. Furthermore, in geriatric patients and those with Parkinsonian gait, respectively, frequency domain analyses can reliably highlight deteriorating gait characteristics [20, 21]. To date, almost all focus on physical activity has been on time spent above or below various thresholds, such as moderate-to-vigorous physical activity, and thus the focus has largely been on quantity. Research seeking to derive measures of quality has largely involved activity in the controlled setting of the laboratory, involving multiple sensors. There has been limited, at best, integration of physical activity quantities and qualities in real-life settings. Notwithstanding, quality is a nebulous term, and can have connotations relating to psychology, physiology, biochemistry, well-being, emotional state, biomechanics or even life. The purpose of this narrative review was to investigate the development of a quantitative measure of physical activity movement quality, with consideration for motor development, fundamental movement skills, energy expenditure and physical activity guidelines.

MATERIAL AND METHODS

A narrative review of literature, defined as a discursive discussion of a relatively broad theme from a theoretical and contextual point of view, was conducted using online databases: Web of Science, PubMed and Google

Scholar, to locate studies published from the journal inception to July 2018. Key search terms included: physical activity, motor development, fundamental movement skills, energy expenditure and movement quality, with the addition of Boolean logic operators 'AND', and, 'OR'.

Multiple searches of each database were conducted with additional searches for relevant references and citations linked to studies obtained during the primary search. The search and selection process sought to locate only peer reviewed articles written in the English language, published in or before July 2018. Subsequently, topics for discussion were identified as: 1) physical activity guidelines, 2) childhood physical activity, 3) motor development, 4) physical activity, 5) fundamental movement and body mass index, 6) physical activity and energy expenditure, 7) physical activity and recess, and 8) physical activity quality.

PHYSICAL ACTIVITY GUIDELINES

It has been recommended that children (5–17 years old) should accumulate at least 60 minutes of moderate intensity physical activity each day [22, 23, 2], whilst for early years children (3–5-year-olds) it is recommended that at least 180 minutes of physical activity is achieved every day (Department of Health [24], Department of Health and Aging [25], Tremblay et al. [26]). Recently, however, a step change has been made in relation to physical activity guidelines. The Canadian 24-Hour Movement Guidelines for Children and Youth were the first to address the whole day [10, 27]. The Canadian 24-Hour Movement Guidelines for Children and Youth encourage children and youth to "Sweat, Step, Sleep and Sit". For optimal health benefits, children and youth (aged 5–17 years) should achieve high levels of physical activity, low levels of sedentary behaviour, and sufficient sleep each day. A healthy 24 hours includes: uninterrupted nine to 11 hours of sleep per night for those aged 5–13 years and eight to 10 hours per night for those aged 14–17 years, with consistent bed and wake-up times, and an accumulation of at least 60 minutes per day of moderate to vigorous PA (MVPA) involving a variety of aerobic activities. Vigorous physical activities and muscle and bone strengthening activities should each be incorporated on at least three days per week, several hours of a variety of structured and unstructured light physical activities, no more than two hours per day of recreational screen time, and limited sitting for extended periods. Preserving sufficient sleep, trading indoor time for outdoor time, and replacing sedentary behaviours and light physical activity with additional moderate to vigorous physical activity can provide greater health benefits [10, 27]. The rationale behind these changes was drawn from a series of comprehensive reviews (see: Saunders et al. [6], Chaput et al. [7], Carson et al. [8] and Poitras et al. [9]). Poitras et al. [9] supported the notion that children and youth accumulate at least 60 minutes per day of moderate to vigorous physical activity for disease prevention and health promotion [1]. Following a systematic review, Poitras et al. [9] reported that total physical activity was positively and significantly associated with physical, psychological/psychosocial, and cognitive health indicators [10, 27]. Relationships were more consistent and robust for higher-intensity compared with lighter-intensity physical activity, whilst light-intensity physical activity was positively associated with cardiometabolic biomarkers. The findings highlight the potential benefits of both light intensity physical activity and total physical activity, neither of which were captured in the previous guidelines [9]. A further review, by

Carson et al. [8], into sedentary behaviour found that higher durations and/or frequencies of screen time and television (TV) viewing were associated with adverse body composition; the frequency and time spent TV viewing was associated with higher cardiometabolic risk; TV viewing and video-game use were associated with adverse behavioural indicators; greater time spent reading and homework were associated with higher scholastic achievement; screen time was associated with lower cardiorespiratory fitness; and screen time and computer use were associated with reduced self-esteem [8]. Screen time has a stronger relationship with health indicators compared with overall sedentary time, and it is concluded that less sedentary behaviour (especially screen time) was associated with better health indicators [8]. A systematic review on the effect of sleep, by Chaput et al. [7], noted that longer sleep duration was linked with positive indicators of adiposity, emotional control, scholastic achievement, and overall health and well-being [7]. Chaput et al. [7] concluded that shorter sleep duration is congruent with detrimental physical and mental health outcomes. Finally, Saunders et al. [6] reported that school-aged children and youth having high physical activity, high sleep, low sedentary behaviour had better measures of adiposity, cardiometabolic health and general health indicators [6]. However, those who had low activity and sleep also had deleterious health indicators [6]. Collectively, the systematic reviews of Saunders et al. [6], Chaput et al. [7], Carson et al. [8] and Poitras et al. [9] provided an evidence base and led to the inception of the 24-hour movement guidelines, targeting a more holistic approach than previously seen. This presents a paradigm change representing a fundamental shift from focusing on behaviours in isolation, to the composition of behaviours across a whole day [9, 6–8]. Consideration for all behaviours along the movement spectrum as a collective is necessary and warranted, and holds promise in the promotion of population health [10].

CHILDHOOD PHYSICAL ACTIVITY

In children and young people (5–18 years of age) there is evidence of the beneficial effects of physical activity on musculoskeletal health, cardiorespiratory fitness, several components of cardiovascular disease, adiposity, and blood pressure [28, 5, 29, 30]. Further physical activity can improve children’s psychological well-being and promote moral reasoning, positive self-concept, and social interaction [31]. Thus, physical activity and fitness in childhood are associated with numerous health benefits [32, 14] and should be promoted [33]. Furthermore, in the late 1980s, Blair et al. [34] hypothesised a number of relationships that linked childhood activity to adult health and adult activity; specifically, (i) childhood physical activity influences adult physical activity, which may affect adult health; (ii) childhood physical activity has a direct beneficial effect on the child’s health, which predicts adult health; and (iii) childhood physical activity has a direct beneficial effect on adult health – this hypothesis has since been supported in the literature [16, 5].

Higher levels of physical activity in children are associated with improved cardiorespiratory fitness and muscular strength [35], enhanced bone health and reduced body fat [36]. Participation in physical activity is vital for enhancing children’s physical, social, cognitive and psychological development [36]. Furthermore, children who frequently participate in physical activity demonstrate reduced symptoms of anxiety and depression, and improved self-esteem and confidence [36]. Whilst children’s activity has been widely investigated, the pre-school period (3 to 5 years of age) is often overlooked, yet pre-school represents a crucial period of development whereby the regulation of energy balance is programmed [37]. For example, lifestyle behaviours are thought to track from pre-school to childhood, and subsequently into adulthood [38, 39], indicating that this is a critical time for promoting physical activity and preventing sedentary behaviours [40]. On the other hand, the relationship between physical activity, sedentary behaviour and health in the early years is not fully understood and warrants investigation [41]. Pivotal to the research is an accurate measure of physical activity that should go over above current approaches [42]. In addition, diversification and refinement on the approaches to measuring physical activity will enable better understanding of these relationships [43]. There has been much debate in the literature into whether young children are sufficiently active for health [44], and conflicting conclusions have been reached. One solution to the dearth of understanding throughout development (i.e. physical activity, motor development and control interaction) is to assess elements of movement quality as well as quantity.

MOTOR DEVELOPMENT

In a seminal study, Stodden et al. [45] proposed a theoretical model that explains the interaction between the development of motor competence, physical activity participation and weight management. Stodden et al. [45] suggested that motor competence is the underlying mechanism that will influence physical activity engagement levels. However, the model asserted that physical activity is also mediated by age, perceived motor competence, physical literacy, health related fitness and obesity risk [45]. During early childhood, the cognitive capability to accurately perceive motor competence is not sufficiently developed [46, 47], whilst in the ages preceding pubertal onset, it has been asserted that this is a critical or sensitive period in the ability of children to develop motor skills [48, 49]. However, when children reach middle to late childhood, their cognitive ability will have developed to the point they compare themselves to their peers [46, 47], resulting in a stronger relationship between motor competence and perceived motor competence. Children who have a higher perceived motor competence and higher motor competence will perceive tasks to be easier and are more likely to engage in physical activity, whereas the reverse is evident in children with low actual and perceived motor competence [50].

Based upon the findings of a comprehensive review, Robinson et al. [51] reported that a positive relationship exists between motor competence and physical activity across childhood, the strength of associations between motor competence and both cardiorespiratory endurance and muscular strength/endurance increase from childhood into adolescence. Finally, motor competence has tenuously been shown to be both a precursor and a consequence of weight status and demonstrates an inverse relationship across childhood and adolescence [51]. Whilst some literature has explored the impact youth physical activity levels have through the life course, there exists little more than tenuous links between early years and childhood motor competence, tracking across the life course. Therefore, adequate measures of motor competence and movement qualities are required to explore this further [42].

PHYSICAL ACTIVITY, FUNDAMENTAL MOVEMENT AND THE BODY MASS INDEX

Fundamental movement skills (FMS) are considered the basic building blocks for movement and provide the foundation for specialised and sport-specific movement skills required for participation in a variety of physical activities. Fundamental movement skills can be categorised into locomotor (e.g., run, hop, jump, leap), object-control (e.g., throw, catch, kick, strike), and stability (e.g., static balance) skills [52]. Current tools to assess FMS, such as the movement ABC test and the gross motor development test, assume that the reliability data and validity information is well founded [53]. However, there is insufficient evidence that clearly indicates the FMS test items are actually evaluating the motor skill constructs [54]. Test-retest and inter-rater reliability has been reported in the literature to range anywhere from 0.49 to 1.00 [55–60].

Despite reliability issues, there is strong evidence to suggest a positive association between fundamental movement skill competency, physical activity and health related benefits in children [61–64]. Many cross-sectional studies have shown a linear relationship between FMS and physical activity. However, cross-sectional data cannot determine causality; for example, it is not clear if FMS influences physical activity or if physical activity influences FMS. In a systematic review on FMS in children and adolescents, Lubans et al. [61] found that FMS was associated with organised and non-organised physical activity and pedometer step counts although ten studies were cross-sectional hindering cause and effect conclusions. Okely et al. [65] found that as little as 3% of organised physical activity was predicted from FMS levels (r^2 =0.03) in 13–16-year-old adolescents, whilst Hamstra-Wright et al. [66] reported that 29% of the variance in locomotor skills was accounted for by organised sport, which is a much higher percentage of variance than reported in the other studies (3% for Okely et al. [65], 10.4% for McKenzie et al. [67], 3.6% for Barnett et al. [68], 19.2% for Cliff et al. [69]).

Previous research has highlighted that FMS is inversely correlated with weight status [70–73], and out of the 21 studies cited in the Lubans et al. [61] systematic review, nine of them used body mass/BMI as a variable to compare FMS mastery. Six of the nine studies highlighted a significant inverse relationship between weight status and FMS mastery. Okely et al. [65] also established that overweight and obese children score lower in the locomotor skills (run, gallop, skip and hop). McKenzie et al. [67], on the other hand, did not find a significant relationship between childhood FMS scores and adolescent physical activity levels, although an inverse relationship between FMS and weight status was identified. The theory is that improving FMS at an early age will result in increased PA and improved health. This is an important concept given that excess body weight is significantly correlated with low physical activity levels, increased all-cause mortality risk and biomechanical movement perturbations [74, 75]. It has been shown that children with excess weight move less and with much greater difficulty than normal-weight peers [75–80], and the impact of excess body mass in children appears to hinder physical activity, movement quality and fundamental movement skill [45, 62]. The compromised movement in overweight children is attributed to greater force through joints, decreased mobility, modification of the gait pattern, and changes in the absolute and relative energy expenditures for a given activity [75, 78]. Furthermore, overweight children have a longer gait cycle and stance phase duration as well as a reduced cadence and velocity compared to normal weight [81-83]. The difficulty overweight children have in adapting to different walking speeds is disadvantageous when participating in physical activities involving frequent speed changes, including standardised fitness tests [78]. Spatiotemporal and kinetic analyses of obese vs. non-obese children showed that obese children were mechanically less efficient than normal weight children, i.e. obese children used more mechanical energy when walking at the same speed, compared to normal weight children [78].

PHYSICAL ACTIVITY AND ENERGY EXPENDITURE

A multitude of instruments providing objective measures of physical activity have been developed, the simplest being pedometers [84], which allow the estimation of distance walked and associated energy expenditure [85, 86]. Whereas, other sensors and methods, including; accelerometers, heart rate monitoring, doubly labelled water, and direct observation have been employed to objectively quantify physical activity and its related energy expenditure [87, 88].

Doubly labelled water is classified as the gold standard of energy expenditure measurement; however, this technique does not measure specific physical activities, per se, but rather estimates total energy expenditure over a period from which the physical activity energy expenditure can be calculated [89]. This method uses non-radio-labelled isotopes of oxygen and hydrogen (^{18}O and ^{2}H) administered as a standard dose of water at the start of the measurement period (usually 7–21 days). The ^{18}O is eliminated from the body in CO_2 and water, and the ^{2}H is eliminated as water only. The difference between the elimination rates of each isotope is an estimate of CO_2 production over the measurement period and the total energy expended during the measurement period can then be calculated using a standard equation [90]. Physical activity energy expenditure can then be calculated by subtracting dietary induced thermogenesis and resting energy expenditure from total energy expenditure [90]. However, physical activity is a complex multidimensional human behaviour that encompasses all bodily movement from fidgeting to marathon running [91, 92]. Consequently, it is important to understand the relationship between specific physical activities and energy expenditure. Types of physical activity may be spontaneous (i.e., daily life activity), obligatory (i.e., activity necessary for survival) or voluntary (i.e., formal, planned exercise) [93]. The major contributor to daily physical activity energy expenditure in children is spontaneous physical activity [94] . There is evidence that low levels of physical activity are associated with increased risk of weight gain and this, in turn, may have health consequences for children [5, 16, 95, 96], hence why the focus of physical activity literature has been on energy expenditure.

Physical activity is a multi-faceted construct and can be expressed and quantified in numerous ways. For example, physical activity can be described according to context, such as surrounding environment and social conditions and further characterised according to type, frequency, duration and intensity [97]. The type or modality of physical activity (recreational, obligatory or occupational, aerobic or anaerobic, continuous or intermittent, weight-bearing or non-weight bearing) refers to the specific activity in which the individual is engaged. The frequency of physical activity refers to the number of bouts of physical activity over time, whilst duration is the length of time in each activity bout. The dose of physical activity, however, may be expressed each activity bout. The dose of physical activity, however, may be expressed according to absolute or relative intensity. Absolute intensity is the actual rate of energy expenditure over a specified time period and is generally expressed as oxygen uptake ($\dot{V}O_2$; $L \cdot min^{-1}$), oxygen uptake relative to body mass ($ml \cdot kg^{-1} min^{-1}$) and/or energy expenditure ($kcal \cdot min^{-1}$, $kJ \cdot min^{-1}$, MJ, $kJ \cdot kg^{-1}$). Absolute intensity can further be described according to multiples of resting energy expenditure using the metabolic equivalents classification (MET). METs are defined as the ratio of energy expended from work to resting metabolic equivalent (3.5 mL of $O_2 \cdot kg^{-1} min^{-1}$) or 1 $kcal \cdot kg^{-1} hr^{-1}$. Knowing the MET value associated with a particular type of activity and individual body mass permits the energy cost of the activity to be estimated [98, 99].

The Compendium of Physical Activities was conceived in 1993 and subsequently revised in 2000 and currently presents MET values for 605 specific activities for adults, categorised under 21 major headings [99, 100]. The values range from 0.9 METs (sleeping) to 18 METs (running at 10.9 mph). MET values are used to express the intensity of physical activity according to intensity categories (i.e., light, moderate, vigorous). Although absolute intensity levels corresponding to MET values exist for children, research is equivocal over which are the most appropriate. In most studies, moderate intensity is defined as ≥3 METs. It is asserted by some that a threshold of ≥5 METs is more suitable for children [101, 102]. More recent evidence suggests ≥4 METs is an appropriate threshold for describing ≥moderate intensity activity in children [101, 102].

A review of physical activity measurement reported that 63% of monitoring devices used were accelerometers, predominantly the ActiGraph [107], whilst literature has focussed on quantifying activity in the form of activity counts, time spent above or below activity thresholds or energy expenditure, as opposed to the movement qualities in real-life settings [108, 109]. Furthermore, functional limitations, such as high frequency movement and noise information escaping the bandpass filter which in turn adds unexplained variation in activity counts [110], variations in the period length, cut points and device type further add to the lack of clarity in the literature [111–113].

PHYSICAL ACTIVITY AND RECESS

Children spend a significant proportion of their waking time at school. Non-curricular time, such as school recess periods (recess and lunch break) and after-school programs, provides opportunities for children to be physically active within the school environment [114, 115]. Of these contexts, recess periods may provide the single greatest opportunity during the school day to impact on children's physical activity levels [116, 117, 79]. However, in recent years there has been a trend to reduce the frequency and duration of school recess, or remove it from the school day altogether, often due to academic pressures [118, 115]. Consequently, it is important that school recess is included in school-based physical activity programming and policy, and that the recess environment is conducive for children to make physically active choices [119]. Whilst the scheduling and duration of recess periods vary between countries, social and physical environments that facilitate enjoyable and safe physical activity engagement in this context would be advantageous [120]. A number of reviews have examined correlates of preschool, children's and adolescents' physical activity [121–123], yet these have predominantly focused on factors associated with whole-day activity. Such work that fails to focus on the playground fails to capitalise on an important opportunity. The playground provides the best environment for correlates linked to physical activity to be meaningfully compared, providing children with the same environment and time for physical activity with few control variables. Since physical activity is a multidimensional behaviour influenced by numerous factors across several domains [124], it is logical to also consider specific contexts in which children and adolescents are active. This notion links to a conceptual model proposed by Welk [125], where the author addressed the area of motor competence. Welk [125] categorised the five most commonly reported determinants/correlates of physical activity into (1) personal, (2) biological, (3) psychological, (4) social, and (5) environmental, and the available literature supports this assertion. Welk [125] suggests in his conceptual model that biological factors, such as physical skills and fitness, act as enabling factors that are promoted by physical activity with increased fitness and competence, leading to increased adherence to physical activity and subsequent enhancement of perceived and actual competence.

Ridgers et al. [123] conducted a systematic review into correlates of physical activity during recess and reported that age, grade level, BMI, cardiovascular fitness, outdoor environment, physical education provision, and number of recess periods had no association with recess physical activity [126–128]. The authors went on to summarise a number of significant, positive associations with physical activity during recess, which included playing ball games, being male, perceived encouragement, loose equipment and overall facility equipment [128–130]. Current research indicates that many correlates of recess physical activity are equivocal, indicating that more empirical research is required [123]; for example, special educational needs, supervision, socioeconomic status, fixed equipment, playground markings, season, temperature, weather, organised activities and recess duration all affect recess activity to varying levels [123]. Whilst an appreciation must also be made for the differences between primary (3–11y) and secondary (12–16y) school aged children. Factors consistently reported to significantly influence primary school aged physical activity levels include; sex (being male), parental overweight status, parent support physical activity preferences, intention to be active, perceived barriers (inverse), previous physical activity, healthy diet, program/facility access, and time spent outdoors [123, 131–135]. Whilst commonly reported factors significantly associated with secondary school aged physical activity are sex (being male), ethnicity (white), age (inverse), perceived motor competence, depression (inverse), previous physical activity, community sports, sedentary time (inverse), and parental support, highlighting that in older age groups (adolescents vs children) social and mental health/well-being factors increase in their influence, whilst biological factors remain constant [123, 131–135].

A further consideration is that a range of physical activity measures have been used to assess physical activity levels, which has a profound influence on the identified associations. While the majority of child studies reported in Ridgers et al. [123] utilised objective measures to quantify physical activity during recess (such as accelerometry and direct observation), aspects such as device type, model type, accelerometer cut-points and observation systems have varied widely, thereby hindering many of the observations [123]. Furthermore, self-report measures are well documented to be less accurate [136]. Therefore, future research should explore how movement quality indicators may be used, in conjunction with traditional quantitative measures, i.e. energy expenditure, overall activity counts [42], and to characterise and profile children's physical activity movement and gait quality.

PHYSICAL ACTIVITY QUALITY

A contemporary problem that needs addressing is a clear definition of 'quality' in a physical activity context. Whilst quantity, with reference to physical activity, is well described, with the most common definition coming in form of the razor coined by Casperson et al. [137], "physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure", the term 'quality' is nebulous and can have connotations relating to physical activity, movement, psychology, physiology, biochemistry, well-being, emotional state, biomechanics or even life.

Quality can be used to describe an individual's overall self-assessment or subjective appraisal of well-being or life satisfaction associated with physical status and functional abilities, mental health, happiness, satisfaction with interpersonal relationships and economic and/or vocational status [138, 139]. For children and youth, there is the additional domain of school/academia [138]. Health-related quality of life includes aspects of overall quality of life that are directly related to physical and/or mental health [138, 139]. As such, health related quality of life reflects the degree to which a person is able to participate physically, emotionally and socially with or without assistance [140].

Social interactions and participation can also be described in terms of quality. Full social participation is considered a fundamental human need, with empirical evidence finding that lack of social connections increases the odds of death by at least 50% [141]. The quality of multidimensional tenets of social relationships have been reported to increase odds of mortality by 91% among the socially isolated [141]. The magnitude of this effect is comparable to that of other known risk factors of mortality, such as obesity or physical inactivity [141, 142]. In humans of all ages, deficits in social relationship quality, such as social isolation or low social support can similarly lead to chronic activation of immune, neuroendocrine, and metabolic systems that lie in the pathways, leading to cardiovascular, neoplastic, and other common aging-related diseases [143–147].

Objectively-measured biomarkers of physical health, such as C-reactive protein, systolic and diastolic blood pressure, waist circumference, and body mass index can be used to indicate physiological quality [148, 149]. For instance, blood pressure may be used to determine the quality and efficiency of the myocardium's ability to distribute and regulate blood flow [148, 149]. Physiological quality may also refer to a molecular and cellular level and the capability to perform basic cellular functions. All cells perform certain basic functions essential for their own survival. These basic cell functions include, but are not limited to: nutrient retention, chemical reactions, waste removal, protein synthesis and reproduction [148, 149]. If any cell within the human system does not perform these basic, and subsequent specialised, functions then the quality of the cell would be considered compromised.

Quality can also be referred to in the context of gait and has been determined using raw accelerations, aligned to anatomical axes with respect to gravity [150–152] and analysis of the bipedal (left-to-right leg) symmetry [153–155].

Quality can be determined from bouts of locomotion and described as vertical trunk displacement [156‒158], stride frequency, and walking speed [156–158]. Whilst gait quality can be described in terms of intensity, expressed as the root mean square of the signal, variability expressed as stride-to-stride variability in walking speed, stride frequency and length, symmetry expressed as the harmonic ratio [159, 160], smoothness expressed as the index of harmonicity [161], and complexity expressed as the mean logarithmic rate of divergence per stride using Wolf's method [162] and sample entropy [163]. Further examples include the autocorrelation at the dominant period [152], the magnitude and width of the dominant period in the frequency domain [164–166] and the percentage of power below 0.7 Hz [167]. However, authors, such as Bellanca et al. [18] and Brach et al. [19], have demonstrated that quality measurements in specific populations can be derived from analysing the fundamental frequency and harmonic content of movement. With the addition of raw accelerometry, novel analytics, such as fast Fourier transformation (FFT), has been used to process the accelerometer signal and identify gait qualities: walking smoothness, walking rhythmicity, dynamic stability and stride symmetry [18, 19]. Operationally, the term 'quality' can be defined and derived from the fundamental frequency spectra (signal) during human movement, specifically relating to ambulation [168]. Following this ontology, the utility of a quantitative measure of movement quality has surreptitiously acquired a reasonable empirical evidence base. Recent evidence has suggested that spectral purity derived movement quality is a viable proxy measure of the fundamental aspects of movement; in pre-adolescent children, this was manifest as significant correlations to cardiorespiratory fitness, time to exhaustion in standardised fitness tests and body-mass indices [169]. Further evidence in pre-adolescents' has demonstrated the sensitivity of movement quality measurement; Clark et al. [170] demonstrated that whilst overall PA remains invariant day-to-day, the quality of movement subsumed in overall PA significantly differs, daily. Whilst in pre-school children spectral purity was shown to be clustered with motor competence and significantly different between motor competency classification, suggesting underlying frequency components of movement need to be further investigated for the measurement of movement quality in children [169, 171]. Moreover, whilst it has been demonstrated that a proxy for overall physical activity was positively, and significantly, correlated with motor competence [61, 172, 64], spectral purity was shown, in Clark et al. [171], to have a stronger relationship to motor competence than overall activity, thereby highlighting the need for future research to examine and further establish this relationship.

CONCLUSIONS

This narrative review has summarised the current evidence base surrounding physical activity and its relationship to health, recess, motor competence/FMS, body mass index and energy expenditure, whilst also appreciating the current physical activity guidelines, all towards the development of a quantitative measure of physical activity quality.

Physical activity is a complex construct and should not be pigeonholed to simply quantity of activity, it may pertain to physical behaviour, movement quality, characteristics of movement, joint angles during movement, force production, motor competency, volume of activity, or even psychological constructs [92]. A substantial amount of research using accelerometers to examine physical activity has focused far more acutely on examining characteristics of movements in a contextualised setting, to later be applied to a wider application [18, 19, 173]. In the literature, the general reference to physical activity refers to the idea of capturing overall quantity; however, physical activity is an umbrella term, for which many things could be inferred. For example, posture classification, movement classification, EE estimation, fall detection or balance and control assessment, frequency component or gait analysis [18, 19]. Physical activity, measured by overall quantity is demonstrably unresponsive to interventions, as a systematic review by Metcalf et al. [174] found that physical activity interventions only improve physical activity quantity, on average, by four minutes per day. Furthermore, Altenburg et al. [175] found interventions specifically designed to target sedentary behaviour are equally ineffective. It is, therefore, this author's recommendation that accelerometers placement and explicit use and application be better defined.

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