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PHYSICAL ACTIVITY, HEALTH AND EXERCISE

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Reliability and validity of using the global school-based student health survey to assess 24 hour movement behaviours in adolescents from Saudi Arabia

Mohummed H Alkhraiji [a,b], Alan R Barker [a] and Craig A Williams [a]

[a]Sport and Health Sciences, College of Life and Environmental Sciences, University of Exeter, Exeter, UK; [b]Department of Exercise Physiology, College of Sport Sciences and Physical Activity, King Saud University, Riyadh, Saudi Arabia

ABSTRACT

This study aimed to examine the reliability and validity of Global School-based Student Health Survey (GSHS) to measure 24-hour movement behaviours (moderate-to-vigorous physical activity - MVPA; sedentary behaviour in the form of recreational screen time - ST; and sleep) in Saudi Arabian youths. A total of 120 (50% female) participants aged 12–15 years old were recruited from eight Saudi public middle schools. Participants completed GSHS survey twice and wore GENEActiv accelerometers for seven consecutive days and completed a diary log. ICC indicated moderate reliability in all 24-hour movement behaviours (ICC = 0.41 - 0.60), whereas ST and sleep were strongly reliable for females only (ICC = 0.61 - 0.80). Kappa agreements for all 24-hr movement behaviours were moderate (k = 0.41 - 0.60), but fair in MVPA and ST for males only (k = 0.21 - 0.40). Spearman's indicated low validity (r = 0.1 - 0.3) in MVPA and sleep between GSHS and GENEActiv. However, kappa test results indicated poor-to-slight agreements (k = <0.00 - 0.2) in MVPA and sleep, but fair in MVPA for males only (k = 0.21 - 0.4). GSHS provided good reliability for single items of 24-hour movement behaviours, and the validity was acceptable and in line with other comparable questionnaires.

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KEYWORDS
Physical activity; sedentary time; sleep; questionnaire; accelerometer

Introduction

Movement behaviours, physical activity in the form of moderate to vigorous intensities (MVPA), sedentary behaviour in the form of recreational screen time (ST), and sleep, are individually associated with health outcomes in children and adolescents (Carson et al., 2017, 2016; Chaput et al., 2016; Saunders et al., 2016). Consequently, there has been an interest in integrating these three movement behaviours across a daily 24-hour period and examining their associations with health status (Tremblay et al., 2016). Recent evidence has shown that meeting the recommendations of these three 24-hour movement behaviours (MVPA ≥60 minutes/day, ST ≤2 hours/day, and night sleep ≥ 9 hours (7–13 years old) ≥ 8 hours (14–17 years old)) concurrently are associated with better health outcomes than meeting none, one, or two of the behaviours in both children and adolescents (Lee et al., 2017; Manyanga et al., 2019; Roman-Viñas et al., 2016).

The Global School-based Student Health Survey (GSHS)is a health surveillance instrument designed for 13–17-year-olds developed by the World Health Organisation (WHO) and the Centre for Disease Control and Prevention (CDC; WHO, 2013). The GSHS is used to provide information for policymakers on health behaviours to help establish, monitor, and evaluate health programs and policies in schools. Since 2003, the GSHS has been used in 103 countries; its data are used to evaluate health promotion programs and compare the prevalence of health behaviours between countries including the prevalence of overweight and obesity (Qi et al., 2021; WHO, 2013). The prevalence of overweight and obesity has been increasing among Saudi adolescents (Al-Hussaini et al., 2019), and adhering to the 24-hour movement behaviours could help to reduce this public health issue (Roman-Viñas et al., 2016; Zhu et al., 2020).

The GSHS examines 10 health risk behaviours and includes single-item questions related to MVPA, ST, and sleep (WHO, 2013). Therefore, data from the GSHS could identify if children and adolescents are meeting the recommended guidelines for the 24-hour movement behaviours (Tremblay et al., 2016). The MVPA data from the GSHS have been used to examine global trends of MVPA among children and adolescents (Guthold et al., 2020; Hallal et al., 2012). In addition, MVPA and total sedentary time data from the GHSH were compared among 34 countries (Guthold et al., 2010). Considering the global use of the GSHS, there is a clear rationale to use it as a globally standardised tool for the assessment of the 24-hour movement behaviours in children and adolescents. This is needed, especially since there is no consensus or a specific worldwide questionnaire for the assessment of the 24-hour movement behaviours (Hidding et al., 2020).

The GSHS metrics of MVPA and total sedentary time (but not sleep) were examined for their reliability in other countries (Haji, 2016; Prochaska et al., 2001). However, this has never been done in the context of the 24-hour movement behaviours, nor are there any data on the validity of the GSHS MVPA and sleep estimates drawn from Saudi adolescents or those from other countries. Therefore, this study aimed to examine the following in adolescents from Saudi Arabia: i) the reliability of MVPA, ST, and sleep as single items from the 24-

CONTACT Craig A Williams c.a.williams@exeter.ac.uk Sport and Health Sciences, College of Life and Environmental Sciences, University of Exeter, St. Luke's Campus, Heavitree Road, Exeter EX1 2LU, Devon

hour movement behaviours using the GSHS; and ii) the validity of the GSHS single items MVPA (60 min/day) and sleep compared to MVPA and sleep assessed using accelerometry.

Methodology

Participants and study design

School children from eight public middle schools in Riyadh, Saudi Arabia, were invited to take part in this study during October and November 2019. Schools, classes, and participants were randomly selected using a computer random generator (www.random.org). Schools were stratified by sex and selected from the Ministry of Education database. The data selected for inclusion in the present study represented a sub-sample (*N* = 120) of participants from Riyadh (the capital of Saudi Arabia) as part of a larger study across Saudi Arabia examining the prevalence of meeting the 24-hour movement behaviours in adolescents. For the purposes of this study, the sub-sample consisted of 120 participants (15 males and 15 females from each school) aged 12–15 years old. Riyadh was divided into four geographical regions (based on the Ministry of Education classification for regions in Riyadh: North, South, East, & West). As the schools were stratified by sex, one middle school for each sex (1 male school and 1 female school) was selected in each geographical region. Each middle school consists of three grades (7, 8 & 9), and from these three grades, two classes were selected and five participants from each grade were recruited, leading to a total of 15 participants from each school. Thus, a random selection of 8 schools (4 male schools, 4 female schools) and 48 classes (24 from each of the male and female schools), provided a sample of 120 (60 males & 60 females) participants for the current study (see, Figures 1 and 2).

The study protocol and procedures were approved by the Institutional Review Board (IRB) at the College of Medicine, King Saud University (No. E-19-3976). In addition, the study was approved by the Ministry of Education in Riyadh (No. 8743). Informed parental consent and participants' assent were obtained prior to data collection.

Timeline for data collection

In week one, the GSHS questionnaire was distributed to all the selected classes in each school. Participants were instructed to complete the GSHS at home and return it to school on the next day (measurement 1). In week two, from the returned GSHS, sub-samples of five participants from each grade with a total of 15 participants from each school were randomly selected (a total sample of 120 participants from the eight schools). The sub-sample participants underwent anthropometric measurements followed by wearing an accelerometer for seven consecutive days. In addition, a diary log was given to the participants to report their MVPA, ST, and sleep behaviours during these seven days. In week three, the accelerometer was collected after seven days of measurement along with the diary log, and then participants completed the GSHS for a second time (measurement 2).

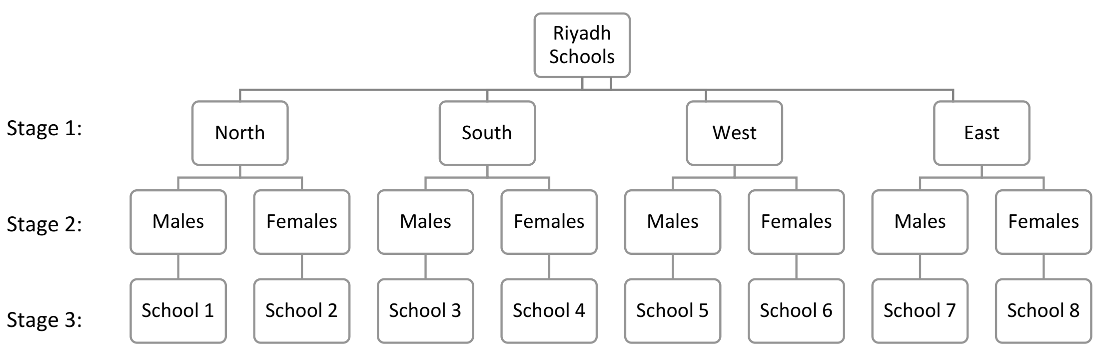

Figure 1. **Stage 1**: Riyadh divisions based on geographical regions. **Stage 2**: Participant classification based on sex. **Stage 3**: Randomly selected school.

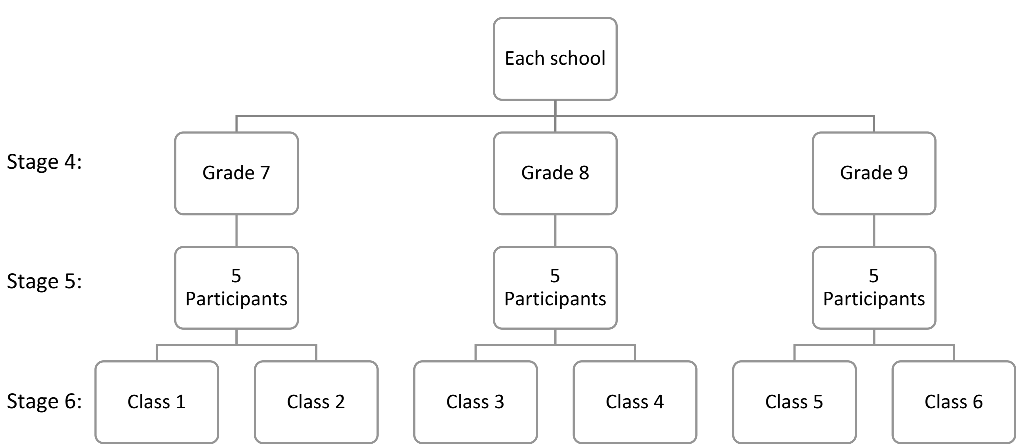

Figure 2. **Stage 4**: Participant classification based on grades. **Stage 5**: Randomly selected class of each grade. **Stage 6**: Randomly selected participants of each class.

Instruments

GSHS questionnaire

The GSHS questionnaire consists of core and core-expanded questions. Core questions are mandatory in each version; the core-expanded questions are optional (WHO, 2018). The GSHS is available in different languages, including Arabic, meaning no translation was required for this study. This study used the 2016 Bahrain GSHS questionnaire version (https://www.cdc.gov/gshs/countries/eastmediter/bahrain.htm; Haji, 2016). The MVPA question asked about the frequency of being engaged in MVPA for at least 60 minutes on each day of the week: "*During the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day? ADD UP ALL THE TIME YOU SPENT IN ANY KIND OF PHYSICAL ACTIVITY EACH DAY*". Before answering the question, participants were provided with a definition of physical activity: any activity that increases their heart rate and makes them get out of breath some of the time, to reflect moderate-to-vigorous physical activity (Prochaska et al., 2001). In response to this question, respondents can choose from 0 days to 7 days. The MVPA data were expressed as the number of days during the week that the participant completed at least 60 minutes of MVPA.

The original ST question in the GHSH focussed on different types of sedentary behaviours: *"How much time do you spend during a typical or usual day sitting and watching television, playing computer games, talking with friends, or doing other sitting activities, such as studying or using any electronic devices like iPads?"* For this study, the ST question was modified to focus on TV and playing computer games to capture recreational ST: *"How much time do you spend during a typical or usual day sitting watching television and playing computer games?"*. Participants could choose from <1 hour/ day, 1–2 hours/day, 3–4 hours/day, 5–6 hours/day, 7–8 hours/day, and >8 hours/ day. Therefore, participants were instructed to answer the ST question as total recreational ST. The ST data were expressed as average recreational screen time per day (min/day).

The sleep question asked about how long the participants spent sleeping on a typical school night (not the weekend), *"On an average school night, how many hours of sleep do you get?"*, with respondents choosing from ≤4 hours/day, 5 hours/day, 6 hours/day, 7 hours/day, 8 hours/day, 9 hours/day, and ≥10 hours/day. The sleep data were expressed as average sleeping duration on a typical school night (hours/night).

Accelerometry

MVPA and sleep were measured using a wrist-worn accelerometer (GENEActiv, Cambridge, UK). The device was set to record MVPA and sleep for seven consecutive days at a frequency of 100 Hz. Participants were instructed to wear the device on their non-dominant wrist for 24 hours for 7 days including water activities. The device was then retrieved, and the raw acceleration data were transformed into epochs of 1 second (Aadland et al., 2020; Mcclain et al., 2008). RStudio's R package GGIR (version 2.3–0) was used to calculate the time participants spent performing MVPA and sleeping (Migueles et al., 2019). Validated age-specific cut-off points of between 20–60 (g/s) for MPA and >60 (g/s) VPA were used (Phillips et al., 2013), and MVPA data were expressed for each day as min/day. For sleep assessment, a validated sleep algorithm was used, which categorised less than 5 degrees of arm angle relative to the horizontal level in 5-minute windows as a sleep period (Van Hees et al., 2015). Weekday sleep data were expressed as min/day.

The GENEActiv wrist-worn accelerometer has a very strong criterion validity ($r = 0.91$) and concurrent validity ($r = 0.84$) for MVPA among children (Phillips et al., 2013), and a criterion validity ($r = 0.91$) for sleep in adults (Van Hees et al., 2015). In addition, GENEActiv (wrist) and Actigraph (hip) accelerometers were found to have a strong correlation ($r = >0.83$, $p = < 0.001$) in children (Rowlands et al., 2014). Moreover, the GENEActiv wrist-worn accelerometer has shown high compliance among children and adolescents compared to the ActiGraph GT3X+ hip-worn accelerometer (Fairclough et al., 2016). In addition, a study on 830 children (9–10 years old) reported that 97.5% met the minimum wear time for four days ($24 – h.d^{-1}$), and 631 (74.1%) over seven days ($24 – h.d^{-1}$; Price et al., 2018).

Diary log

The diary log was used to report the three components of the 24-hour movement behaviours for seven days. Participants were instructed to self-report all of the three movement behaviour activities at any time during the day. The columns in the diary log were labelled as follows: day, wake up time, TV viewing, playing computer games, doing physical activity, and sleeping time. All variables were reported in min/day.

Anthropometrics

Body mass was measured to the nearest 0.1 kg using a commercial body mass scale (SECA 869, Birmingham, UK), with minimal clothing and without shoes. Stature was measured to the nearest 0.1 cm using a calibrated measuring rod (SECA 213, Birmingham, UK) with the participant in a full standing position without shoes. Body mass index (BMI) was assessed using sex-specific BMI-for-age percentile growth charts (Kuczmarski, 2000).

Data analysis

Participants were classified as meeting the MVPA guideline if any participants were engaged in MVPA for at least 60 minutes per day for seven days either using the GSHS, GENEActiv accelerometer or diary log (WHO, 2010). Participants were classified as meeting the ST guideline if their average total screen time for TV and/or computer games was ≤ 2 hours per day for the GSHS or diary log (Tremblay et al., 2016). Participants were classified as meeting the sleep guideline if their average sleep duration on a typical school night was ≥ 8 hours per day either using the GSHS, GENEActiv accelerometer, or diary log (Hirshkowitz et al., 2015).

Table 1. Participant characteristics: mean (SD), percentage, and median (percentiles).

	Male	Female	
	N = 60	N = 60	p-value
	Median (percentiles)		
Age (y)	14 (13–15)	14 (13–14)	0.921
	***N* = 59**	***N* = 60**	
	Mean (SD)		
Stature (m)	1.55 (0.09)	1.53 (0.06)	0.106
Body mass (kg)	55.0 (15.5)	52.8 (14.3)	0.414
Body mass index (kg/m^2)	22.50 (5.42)	22.24 (5.29)	0.936
BMI Classifications	***N* (% of sample)**		
Underweight	3 (5.1)	4 (6.7)	
Normal	49 (83.1)	48 (79.9)	0.997
Overweight	6 (10.2)	7 (11.7)	
Obese	1 (1.7)	1 (1.7)	
GHSH (measurement 1)	***N* = 60**	***N* = 60**	
	Median (percentiles)		
MVPA days/week	1 (0–3)	2 (0–5)	0.227
SB by hour/day	3* (2–4)	3* (2–4)	0.333
Sleep min/weekday	420 (375–480)	420 (360–540)	0.847
GHSH (measurement 2)	***N* = 59**	***N* = 58**	
	Median (percentiles)		
MVPA days/week	2 (1–3)	2 (1–3)	0.931
ST by hour/day*	3* (2–4)	3* (2–4)	0.993
	Mean (SD)		
Sleep min/weekday	420 (360–480)	420 (360–480)	0.420
GENEActiv	***N* = 57**	***N* = 60**	
	Median (percentiles)		
MVPA days/week	5 (2–6)	2 (0–5)	**<0.001**
	Mean (SD)		
Sleep min/weekday	438 (60)	399 (72)	**0.002**
Diary Log	***N* = 47**	***N* = 50**	
	Median (percentiles)		
MVPA days/week	1 (0–3)	0 (0–2)	0.080
	Mean (SD)		
ST by min/day	175 (130)	166 (113)	0.954
Sleep min/weekday	435 (65)	415 (68)	0.140

Figures in bold denote significant differences between the sexes ($p < 0.05$), BMI = Body Mass Index, MVPA = moderate-to-vigorous physical activity, ST = screen time.
*3-4 hours/day.

Statistical analysis

Descriptive characteristics (mean, SD, median, and percentiles) for MVPA, ST, and sleep across all instruments (GSHS, GENEActiv, and diary log) were provided for all participants by sex. All data were examined for normality using the Kolmogorov Smirnov test. The Mann–Whitney test (non-parametric data) was used to compare the absolute values of each movement behaviour between sexes. The Friedman test was used to examine if there were significant differences between MVPA, ST, and sleep across instruments, and a post hoc analysis was conducted if needed using the Wilcoxon signed-rank test (non-parametric data).

To assess the reliability (week 1 vs. week 3) of the MVPA, ST, and sleep single items using the GSHS, the intraclass correlation coefficient (ICC) was used based on a two-way random effects model (Weir, 2005). The test-retest reliability ICC values were classified as slight (0–0.2), fair (0.21–0.4), moderate (0.41–0.60), good (0.61–0.80) and excellent (0.81–1.00; Shrout, 1998). In addition, kappa statistics and percentage agreement were used for dichotomous reliability (meeting/not meeting the guidelines). Kappa test values were classified as poor (K < 0.00), slight (K = 0–0.2); fair (K = 0.21–0.4); moderate (K = 0.41–0.60); substantial (K = 0.61–0.80) and almost perfect (K = 0.81–1.00; Landis & Koch, 1977).

To examine the concurrent validity of the MVPA and sleep single items using the GSHS against the GENEActiv accelerometer and diary log, Spearman's rank-order correlations (r) were used (nonparametric data) to assess the relationships among all instruments. Spearman's r was classified as weak (0.1–0.3), moderate (0.4–0.6), strong (0.7–0.9) and perfect (1; Akoglu, 2018). For the dichotomous variables (meeting/not meeting the guidelines), kappa statistics were used to identify the agreement between all instruments in each single movement behaviour and classified as previously mentioned.

Results

Participant characteristics

Table 1 lists the participants' characteristics and missing data. There were no significant differences between males and females in all characteristics, except for MVPA and sleep, which were both higher in males when measured via the GENEActiv accelerometer.

On the anthropometrics test day, one male participant (1.6%) was absent. On the GSHS (measurement 2) test day, one male (1.6%) and two females (3.3%) were absent. The GENEActiv data were retrieved for all participants; however, data for three males (5%) could not be analysed due to file errors. Diary logs were not returned by 13 male (21.6%) and ten female (16.6%) participants.

Table 2 illustrates the reliability of the GSHS 24-hour movement behaviour for single items using the ICC for ranked data, and kappa for meeting or not meeting the guidelines. Across all the 24-hour movement behaviours in male participants, the ICC values were moderately (ICC = 0.41–0.6) correlated; in females, the ICC values were good (ICC = 0.61–0.8). In terms of classifying as meeting the guideline or not, in males, the kappa agreement was fair for MVPA (k = 0.34) and ST (k = 0.30), but moderate for sleep (k = 0.41). In females, all the 24-hr movement behaviours showed moderate agreement (k = 0.41–0.60).

Table 3 presents the validity of the GSHS with GENEActiv and diary log. In both sexes, the agreement between movement behaviours using the GSHS and GENEActiv was weak (r = 0.1–0.3). This was similar between movement behaviours using the diary log and GENEActiv, except for sleep, which was

Table 2. Reliability of the GSHS 24-hour movement behaviours single items using the ICC for ranked data, and Kappa for meeting or not the guidelines.

		(95% CI)				
GSHS	ICC	Lower Bound	Upper Bound	p-value	Kappa	% Agreement
Males (N = 59)						
MVPA	0.606	0.331	0.759	**0.003**	0.37	94.9
ST	0.556	0.263	0.734	**0.019**	0.30	66.1
Sleep	0.472	0.114	0.686	**0.001**	0.41	71.2
Females (N = 58)						
MVPA	0.623	0.365	0.777	**0.000**	0.47	87.9
ST	0.721	0.527	0.835	**0.001**	0.44	72.4
Sleep	0.788	0.642	0.875	**<0.001**	0.50	75.9

Figures in bold denote significance ($p < 0.05$).
MVPA = moderate-to-vigorous physical activity, ST = screen time.

Table 3. The validity of the GSHS compared with GENEActiv and diary log data using Spearman's rank-order correlations data and kappa for meeting or not meeting the guidelines.

Instruments	Movement Behaviours	Spearman's (p-value)	Kappa
Males			
(*N* = 57)			
GSHS compared to GENEActiv	MVPA	0.187 (0.167)	**0.300**
	ST	– –	– –
	Sleep	0.245 (0.069)	0.072
(N = 47)			
GSHS compared to Diary log	MVPA	**0.632 (<0.001)**	**0.393**
	ST	**0.575 (<0.001)**	**0.461**
	Sleep	**0.457 (0.001)**	**0.290**
(N = 47)			
GENEActiv compared to Diary Log	MVPA	0.159 (0.296)	0.182
	ST	– –	– –
	Sleep	**0.446 (0.002)**	0.271
Females			
(*N* = 58)			
GSHS compared to GENEActiv	MVPA	**0.276 (0.036)**	0.158
	ST	– –	– –
	Sleep	0.189 (0.156)	0.029
(*N* = 53)			
GSHS compared to Diary log	MVPA	**0.436 (0.001)**	−0.058
	ST	**0.287 (0.039)**	**0.305**
	Sleep	**0.346 (0.013)**	**0.320**
(*N* = 53)			
GENEActiv compared to Diary Log	MVPA	0.218 (0.118)	**0.372**
	ST	– –	– –
	Sleep	**0.493 (<0.001)**	**0.387**

Figures in bold denote significance ($p < 0.05$).
MVPA = moderate-to-vigorous physical activity, ST = screen time.

moderately correlated (r = 0.4–0.6). The overall agreements between movement behaviours using the GSHS and diary log were moderate (r = 0.4–0.6).

Discussion

To the best of our knowledge, this is the first study to examine the reliability and validity of measuring the 24-hour movement behaviours among adolescents from Saudi Arabia using the GSHS and device-based measurement. The findings showed that the GSHS had a moderate ICC reliability in males across the three 24-hour movement behaviours; in females, the ICC reliability was classified as good. However, the reliability of the 24-hour movement behaviours based on meeting or not meeting the guidelines revealed fair-to-moderate agreement in males and moderate agreement in females. In addition, the validity of the GSHS, MVPA, and sleep data against the GENEActiv accelerometer data revealed a weak positive association in both males and females.

Reliability

The reliability of the MVPA and ST data derived from the GSHS was lower than the GSHS reliability study reported by Ziaei et al. (2014), which used Kendall's tau for MVPA (b = 0.73) and total sedentary time (b = 0.81; Ziaei et al., 2014). This could be due to the different age group investigated by Ziaei et al., who recruited participants aged 15–17 years old; it has been reported that older adolescents achieve higher reliability values in the assessment of MVPA (Booth et al., 2001; Rangul et al., 2008), which might also be the same case for ST. In addition, Ziaei et al. (2014) did not separate the results by sex; there is evidence indicating differences in reliability outcomes between the sexes, with females having better reliability than males (Rangul et al., 2008). Therefore, combining the results of both sexes might be misleading in assessing reliability. Also, a GSHS reliability study by Becker et al. (2010) conducted on females (15–20 years old) achieved a similar reliability kappa agreement for MVPA (κ = 0.43 vs. κ = 0.47) but a lower ST (κ = 0.3 vs. κ = 0.44) compared to the female participants in the current study (Becker et al., 2010). The differences in ST could be explained by the modifications made to the ST question in the current study, which is specific to time spent watching TV and playing computer games. This might explain why in the present study the reliability for ST was higher compared to that reported in Becker et al. (2010) as recalling time spent watching TV and playing computer games may be more memorable than total sedentary time, which includes may different domains. In regard to sleep measured via the GSHS, the authors are not aware of any studies that have examined its reliability.

The ICC values for MVPA, ST, and sleep reliability in the present study were found to be lower than those reported using the Health Behaviour in School-aged Children (HBSC) survey among adolescents aged 11–15 years old (Liu et al., 2010). The current study's MVPA (r = 0.60 vs. r = 0.79), ST (r = 0.55 vs. r = 0.64) and sleep values (r = 0.47 vs. r = 0.73) were lower in males. However, in females the reliability values for MVPA were lower (r = 0.62 vs. r = 0.87), the values for ST were higher (r = 0.72 vs. r = 0.67), and the values for sleep were similar (r = 0.78 vs. r = 0.75; Liu et al., 2010). Although both the GSHS and HBSC show ICCs that mostly range from moderate to good, the reliability of the HBSC was slightly higher than the GSHS. This could be due to the differences in the number of questions related to each movement behaviour in the HBSC, which can capture more detailed information (for example, specific questions related to MVPA and vigorous physical activity (VPA)) than the GSHS, which only asks one question related to each of the movement behaviours. This also applies to the reliability of other comparable questionnaires that feature a greater number of questions such as the Physical Activity Questionnaire for Older Children (PAQ-C) and the Adolescent Sedentary Activity Questionnaire (ASAQ; Hardy et al., 2007; Zaki et al., 2016). Therefore, although having more questions related to a single movement behaviour could result in better reliability, there is evidence to show that this approach does not differ significantly from a single-question approach. A study on 123 adolescents (14.7 ± 0.5 years) compared the reliability of the Oxford Physical Activity Questionnaire (OPAQ) to a single-item question to measure MVPA (*In the past week, on how many days have you done a total of 60 min or more of physical activity, which was enough to raise your breathing rate? This may include sport, exercise and brisk walking or cycling for recreation or to get to and from places'*). This study found a close similarity between the ICC for the OPAQ (0.79) and a single-item question in determining MVPA (0.75; Scott et al., 2015). Overall, systematic reviews reveal that the median reliability for youth MVPA questionnaires achieves an ICC of 0.69, and for sedentary behaviours, an ICC of between 0.20–0.85 (Helmerhorst et al., 2012; Hidding et al., 2017).

Validity

This study found a weak positive association for determining MVPA between the GSHS and GENEActiv accelerometer in males (r = 0.18) and females (r = 0.27). Interestingly, the GSHS underestimated the engagement in the number of days on which 60 minutes of MVPA was performed across both males and females, but it was only significant in males compared to the GENEActiv accelerometer. This finding contradicts the findings in the literature as children and adolescents tend to overestimate their MVPA using questionnaires (Adamo et al., 2009). The underestimation of MVPA in the current study may be because the participants (aged 12–15) were less aware or not able to recall the periods of bouts that are considered to be MVPA, such as playing with friends, walking to school, walking fast, etc (Armstrong & Bray, 1991; WHO, 2013).

The authors are not aware of any concurrent validity data related to the 24-hour movement behaviours (MVPA and sleep) single-item questions measured using the GSHS. A few studies, however, have examined the validity of the single-question MVPA (which is similar to the MVPA questions used in the GSHS and features the same responses scale) against device-based measurements. A study conducted on 138 adolescents (65% females) mean age 12.1 ± 0.9 years old validated the MVPA single-item question against the Computer Science and Applications (model 7164) accelerometer and reported correlations of r = 0.42 and r = 0.32 for males and females, respectively (Prochaska et al., 2001). Also, a study on male (*n* = 74) and female (*n* = 46) adolescents mean age 14.7 ± 0.5 years old examined the validity of MVPA single-item questions against Actigraph (GT3X),which found a correlation of r = 0.44 (Scott et al., 2015). The PA single-item validity values in the two above-mentioned studies were, therefore, both higher than that observed in the current study. An explanation for these inter-study discrepancies could be related to the use of hip-worn accelerometers in previous research, whereas, in the current study, the GENEActiv accelerometer was wrist-worn. A systematic review reported that in children, hip-worn accelerometers are more accurate in detecting MVPA than their wrist-worn counterparts (Lynch et al., 2019).

In addition, the validity of the GSHS MVPA data from the current study is highly similar to those of other comparable questionnaires that have multiple-item MVPA questions such as the HBSC and the PAQ-C questionnaires (validity: r ≈ 0.34; Tanaka et al., 2017; Wang et al., 2016). In general, the variations in the validity of these studies could be due to the use of different accelerometer brands, software, length of epochs, and algorithms, all of which can affect the assessment of MVPA and lead to different interpretations (Aadland et al., 2020; Van Hees et al., 2010, 2016). For example, in the present study, the accelerometer brand was GENEActiv, the software used was R, epoch length was 1s, and GGIR package algorithms were used. In contrast, other studies used the ActiGraph accelerometer and different software such as Actilife 5 and Q-basic, which have their own specific algorithms, and use different epoch lengths such as 15s and 60s (Prochaska et al., 2001; Scott et al., 2015). However, a systematic review has reported that in terms of median validity for children and adolescents MVPA questionnaires using Spearman's correlation coefficient achieve a reliability value of r = 0.22 (Helmerhorst et al., 2012), which is close to the values found in the current study (males: r = 0.18; females: r = 0.27).

The validity of the GSHS sleep data compared to that of the GENEActiv accelerometer revealed a weak positive association in males (r = 0.24) and females (r = 0.18). The GSHS underestimated sleep in males compared to the GENEActiv accelerometer, but this was not significant. However, in females, the GSHS overestimated sleep compared to the GENEActiv accelerometer. The low validity of sleep data could be attributed to the fact that children and adolescents overestimate sleep time when using questionnaires compared to accelerometers (Gaina et al., 2004; Mazza et al., 2020; Williams et al., 2013). In addition, in Saudi Arabia, school children commonly take an afternoon nap after school, which can range from < 3 hours/ day to > 3 hours/ day (Nasim et al., 2019). Therefore, the night sleep time data might be inconsistent, which could affect the accuracy of the reporting of sleep duration using the GSHS questionnaire. However, the validity of the sleep data gathered using the GSHS in the current study is low compared to the literature. One study validated a self-developed sleep questionnaire among adolescents aged 13–14 years old who wore an Actiwatch accelerometer for seven consecutive days. This study used the Pearson correlation coefficient and found low validity correlations in sleep period time in males (r = 0.394) and females (r = 0.385; Gaina et al., 2005). Another study validated the Sleep Timing Questionnaire (STQ) among children aged 11–12 years old, and adolescents aged 14–15 years old and 15–16 years old (11.9 ± 1.42) who wore an ActiGraph monitor for seven consecutive days. This study used the Pearson correlation coefficient, which found moderate correlations in weekday sleep onset (r = 0.76) and weekday wake time (r = 0.45; Tremaine et al., 2010). The high correlations between weekday sleep onset and weekday wake time in the two above-mentioned studies compared to those of the current study could be because including more questions related to sleep helps the participants to provide more accurate responses, rather than GSHS which only asks a single question. However, while a systematic review and meta-analysis examining the validity of sleep time questionnaires in children and adolescents reported moderate-to-strong criterion validity, most validity studies examined parents' reports of their children and adolescents' sleep patterns (Nascimento-Ferreira et al., 2016).

The present study features four main strengths: (i) having a random sample, including both sexes; (ii) analysing separate sex-based data (not combined); (iii) using raw acceleration data retrieved into epochs of 1 second; and (iv) using the GGIR package. Despite its merits, the present study is also subject to three crucial limitations: (i) the GSHS only measured MVPA for 60 min/day over seven days, which does not account for the total volume of MVPA per week; (ii) ST was limited to TV viewing and playing computer games; this neglects iPad and mobile use, which could account for more recreational screen time in these participants; (iii) sleep time was limited to school nights only; this ignores weekend sleep time, which was found to be longer (Bauducco et al., 2016).

Implications of the use of the GSHS questionnaire and suggested future directions for studies addressing the question of sedentary time; sleep, and 24-hour movement behaviours

- The question on sedentary time should be split into two items to capture non-sedentary recreational screen time and sedentary recreational screen time. Or the first part of the question could be omitted to capture only recreational screen time (as in the present study).
- The question on sleep duration should include all nights (not only weekdays), and another question to investigate sleep duration during the day should be included (this is specific for populations in which daytime naps are common).
- If possible, each question related to 24-hour movement behaviours could be separated into two items divided into weekdays and weekends.

Conclusion

When investigating the associations between movement measured using questionnaires and health outcomes, valid and reliable tools are important methodological considerations (Adamo et al., 2009). This study has found that the GSHS offers good reliability in measuring the 24-hour movement behaviours among children and adolescents. In addition, while the current study found the GSHS questionnaire offers acceptable validity for measuring MVPA and sleep, the validity correlations were somewhat weak and should be used with caution. Overall, these reliability and validity findings are similar to other international questionnaires designed to measure different single-movement behaviours (Helmerhorst et al., 2012; Hidding et al., 2017; Yang et al., 2020). This suggests there is scope to use the information from the GSHS as a tool to assess 24-hour movement behaviours in children and adolescents. However, future work is needed to improve the validity of the GSHS MVPA and sleep. In addition, as reliability and validity studies are population-specific, future studies are needed to investigate comparable populations in different countries using this same method to confirm our findings.

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ORCID

Mohummed H Alkhraiji http://orcid.org/0000-0002-7935-4252
Alan R Barker http://orcid.org/0000-0001-8610-5417
Craig A Williams http://orcid.org/0000-0002-1740-6248

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