Not all sedentary behavior is equal: children's adiposity and sedentary behavior volumes, patterns and types.

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ABSTRACT

Objective: The importance of different constructs of sedentary behaviors in relation to childhood obesity is uncertain. Thus, this study aimed to investigate relationships between volume, patterns and types of sedentary behavior and adiposity in children. **Methods:** A case-control study was undertaken involving 234 children aged 10-13 years who were either of a healthy-weight (74 boys, 56 girls) or classified as obese (56 boys, 48 girls). Percent body fat (by dual-energy X-ray absorptiometry) and waist-to-height ratio were assessed. Time, type (television, videogame, computer, eating, passive transport) and bout length of sedentary behaviors were measured using accelerometry and the Multimedia Activity Recall for Children and Adolescents. Time use (total daily energy expenditure, sleep, physical activity), age, household income and Tanner stage were covariates in sex-stratified partial least squares analyses. **Results:** Daily energy expenditure and income were negatively associated with adiposity for both sexes. Television time was consistently positively associated with adiposity. In boys only, prolonged bouts of sedentary behavior and time spent playing video games/computer were positively linked with adiposity. Non-screen sedentary behavior was negatively associated with adiposity in girls. Independent of total energy expenditure, total sedentary time was only inconsistently associated with fatness. **Conclusions:** These data suggest that (1) characteristics of sedentary time other than duration are associated with adiposity in children, and (2) associations may be sex-specific.

Keywords: percent body fat, child, television, physical activity, screen time, obesity

1 INTRODUCTION

Childhood obesity is a global issue that poses a serious public health challenge. The role of a healthy diet and physical activity in preventing childhood obesity is well established, and there is considerable interest in the role of sedentary behavior (i.e. activity done seated/reclining, requiring ≤1.5 times resting metabolic rate) [1]. Notably, the relative importance of total *volume* (i.e. duration) of sitting, *patterns* of sitting (e.g. bout length) and *types* of activities performed while sitting (e.g. television, passive transport etc.) [2] is unclear; especially when considering other movement behaviours (like sleep and physical activity) [3].

Randomised controlled trials consistently demonstrate that decreased sedentary time *volume* leads to reductions in body mass index (BMI) [2]. However, these trials did not always adjust for changes in moderate-to-vigorous physical activity (MVPA), and a more recent meta-analysis [4] found little high-level evidence that total volume and patterns of sitting are associated with health outcomes in children after adjustments for MVPA. These analyses also mirror the updated descriptive synthesis/systematic review by Carson et al [3] which considered data from fully adjusted models (where available). Furthermore, most literature relies on surrogate measures of body composition (e.g. body mass index) and there is a dearth of studies examining body fat, especially using accurate measures such as DXA (dual energy X-ray absorptiometry).

Research in adults suggests that *patterns* of sedentary behavior may have important implications for overweight/obesity, [5] but evidence in children is sparse [3, 6]. Few pediatric studies have explored time spent in uninterrupted periods of sitting, or bouts and breaks in sedentary time [7-10]. These studies have largely used non-gold-standard measures of fatness and have short follow-up periods.

There is increasing evidence that not all *types* of sedentary behaviors are associated with equivocal health risks [3, 6, 11]. Most literature has focused on television viewing, consistently reporting a positive relationship with overweight/obesity/adiposity [2, 3]. Although much literature in this field uses self- or parent-reported television viewing measures, often with unknown psychometric properties [3, 6]. Furthermore, little attention has been directed to non-screen sedentary behaviors, such as time spent eating or in passive transport [2, 3].

Recent high level evidence has highlighted a need for improved methodologies around the measurement of sedentary behaviors. Specifically, there is a call for studies combining objective and subjective methods (with sound psychometric properties), to examine multiple domains of sedentary time (i.e. duration, type and patterns), while also considering other key behaviors such as sleep and physical activity [3, 6]. Thus, the current study aimed to investigate relationships between volume, patterns and types of sedentary behaviors and adiposity in obese and healthy-weight children, with appropriate consideration of related movement behaviours (namely sleep and physical activity). We hypothesised positive relationships between sedentary behavior variables and adiposity. This study also aimed to address further limitations of previous research by incorporating rigorous methods to assess sedentary behaviors, along with gold-standard body fatness measures.

2 METHODS

2.1 Participants

Data from a larger multi-centre, case-control study [12] that recruited obese and healthy-weight 10-13 year olds from three Australian states in 2008 - 2009 (South Australia, Victoria and Queensland) was analysed. Participants with a medical condition/disability, recent acute injury/ear infection/balance disturbance/weight loss intervention or who were underweight/overweight were excluded. Ethical approval was obtained from the University of South Australia, RMIT University, Queensland University of Technology and Flinders Medical Centre Human Research Ethics Committees. Parents/carers provided written informed consent and children gave verbal assent.

2.2 Measures

2.2.1 Body composition

Height and body mass were measured as previously described with participants wearing a hospital gown [12]. Weight status was classified using International Obesity Task Force criteria [13]. Waist circumference was measured at the midpoint between the lower costal margin and iliac crest against the skin (Lufkin WOW6PM Executive Thin Line anthropometric tape, USA). Waist-to-height ratio (WHtR) was calculated. Percent body fat (%BF) was assessed using dual energy X-ray absorptiometry (DXA: Lunar Prodigy with standard software ENCORE 2003, version 7.52, General Electric Medical Systems, Madison, USA). DXA has been shown to have excellent validity (compared with chemical fat analysis of pediatric weight pig carcasses) [14] and reliability in our laboratory is excellent [test re-test reliability, intraclass correlation coefficient (ICC) 0.999 for %BF in a sub-sample of 23 obese/healthy-weight children).

2.2.2 Sedentary behaviors

Volume

Sedentary behavior volume was assessed using uniaxial accelerometry, sampling in 60 s epochs, (Actigraph® version 2.2 model 7164; ActiLife analysis software version 3.2.6, MTI Health Services, Florida, USA). Participants were requested to wear the accelerometer on their right hip for eight consecutive days (including overnight and excluding water-based activities). Non-wear periods were identified as ≥60 consecutive minutes of zero counts [15]. Minimum inclusion criteria were ≥3 weekdays plus one weekend day with ≥10 waking hours of wear time [15, 16]. Sleep periods were excluded from the analysis (manually identified as periods of continuous low counts corroborated with interview data). Sedentary behavior was defined as 0-100 counts per minute

(CPM) [17]. Total sedentary time volume was computed as average minutes/day, normalised for accelerometer wear time (average minutes/day of ≤100 CPM/total wear time), but are presented as a percentage (X 100) for interpretability.

Patterns

Using accelerometry data, the percentage of time spent in prolonged bouts of sedentary behavior (<100 CPM) lasting ≥30 minutes was quantified [7]. The length of the bout was chosen to reflect a common sedentary activity (30 minute television show) [9]. A break was considered as an interruption in sedentary time (lasting ≥one minute) in which there was a transition in accelerometer counts from <100 CPM to >100 CPM. Since participants may have worn the accelerometer for different lengths of time, prolonged sedentary time was normalised for sedentary time (average minutes/day in bouts ≥30 minutes/total sedentary time) and were presented as a percentage (X 100) for interpretability.

Types

Average daily minutes spent in six categories of sedentary behavior [television, computer, videogames, eating, passive transport and non-screen sedentary behavior (eating and passive transport)] were derived using the Multimedia Activity Recall for Children and Adolescents (MARCA; a valid and reliable computer-based 24-hour use-of-time tool) [18, 19]. Inter-rater reliability was also shown to be acceptable in a sub-sample (n = 23) of obese and healthy-weight children from this study (ICC 0.7-0.8 for sleep, physical activity level and screen time minutes). The MARCA was interviewer-administered by telephone during the school term over two appointments, each recalling the prior two days (two school days and two non-school days in a week). Minimum inclusion criterion were one school day and one non-school day. The weight status of participants was undisclosed to interviewers. Strategies aimed at improving recall accuracy were used including day segmentation (by waking, sleeping, break and mealtimes), ensuring all 24 hours were accounted for, along with probing questions to check for activity ommissions (e.g. asking children if they packed their school bags, took toilet breaks etc.). Each MARCA activity was linked to an energy-expenditure compendium [20] so that PAL (Physical Activity Level, or total daily energy expenditure in METs) could be calculated. Time-use data were weighted 1:1 for school days: non-school days as children spend ~one day in two in school over a year.

2.2.3 Physical activity

Using accelerometry, time spent in MVPA (average min/day) was computed per participant using the pediatric Evenson cut-points [17]. Data were normalised for total accelerometer wear time (minutes/day of MVPA/total wear time) for analyses and were presented as a percentage (X 100) for interpretability.

2.2.4 Sleep

Sleep periods were manually identified using accelerometry. Plots of counts against time were examined per-subject. Sleep times, identified by periods of continuous low counts and corroborated with MARCA interview data, were marked and isolated. Three sleep variables were included in the analysis: sleep duration (average minutes/day); bedtime and waketime (each expressed as average minutes post midnight/day, but presented as 24 hour time in hour: minutes for interpretability).

2.2.5 Demographics

A parental questionnaire captured annual household income [12]. Participants self-rated their pubertal development using the Tanner scales [21].

2.3 Statistical analysis

Descriptive analyses were undertaken using SPSS (version 25, International Business Machines Corp., New York) comparing boys and girls using either a Student's Independent Sample's T Test (normally distributed interval data), Exact Mann Whitney U Test (non-normally distributed data) or a Chi Square Test (ordinal data). A P value of ≤ 0.05 was taken as significant.

Partial least-squares (PLS) is a regression technique used when there are a large number of inter-correlated predictor variables. It transforms predictor variables into 'components' that are that are then regressed against the dependent variables of interest. The relative contribution of predictors within the components can then be unpacked using the Variable Importance in Projection (VIP) statistic. A VIP ≥ 1 is considered to be important [22]. The model equation in the output reveals directionality of relationships (i.e. positive or negative). The dependent variables were %BF and WHtR. In addition to sedentary behavior variables, income, age, PAL, MVPA, Tanner stage, sleep duration, bedtime, and wake time were entered as covariates. Data were sex stratified. Partial least-squares regression was performed using single-fold, 100 round cross-validation with automatic stop conditions (default 100 permutations) and variables were centred and reduced. The cumulative Q^2 index and the percentage of variance in body composition explained by the component were examined to ascertain whether one component was sufficient. Expectation maximization was used to impute missing data to reduce bias [23] and data were confirmed missing completely at random using Little's test [24] ($p=0.61$ and $p \geq 0.99$, conducted using SPSS). A sample size of 104 is capable of detecting a coefficient of determination (r^2) of <0.2 using 16 predictor variables (alpha 0.05, 80% power). Analyses were performed using XLSTAT for Windows 2016 (Addinsoft, New York, USA).

3 RESULTS

The final sample comprised of 130 boys (56 classified as obese, 74 classified healthy-weight) and 104 girls (48 classified as obese and 56 classified as healthy-weight) . Descriptive characteristics are shown in Table 1. Excluding sleep, participants spent >50% of their day sedentary, with >10% of their sedentary time in extended bouts lasting >30 minutes. When examining types of sedentary behaviors, television dominated (2.75 hours/day). Differences between sexes were also observed with boys watching 37 min/day more television than girls (difference in medians). Boys also spent significantly more time using video games than girls (differences in medians of 29 min/day). Slight gender differences in non-screen time time, particularly passive transport were observed (median values in girls 6-8 min/day higher), but these differences did not reach significance (Table 1).

Partial least-squares regression revealed one major component (comprising of 16 predictor variables shown in Figures 1 and 2) which in boys, explained 36% and 18% of the variance in %BF and WHtR respectively. In girls, the same component explained 23% of the variance in %BF and 24% in WHtR. The VIP scores are presented in Figures 1 and 2. Given that VIP is a descriptive technique, 95% confidence intervals are provided to demonstrate variance, but are not considered indicators of significance.

In boys, PAL ranked as the most important correlate with %BF/WHtR. Although VIP scores do not show directionality of the relationship, the model equation revealed that increased PAL was associated with lower %BF/WHtR. Parental income also had a negative association, while time spent in sedentary bouts, watching television and using computers were all positively associated with %BF/WHtR. Videogame use was positively associated in boys only with %BF, while total sedentary time was negatively associated only with WHtR.

In girls, time spent watching television ranked as having the greatest positive relationship with both %BF and WHtR. Physical activity level, income, non-screen sedentary behavior and passive transport also all had VIPs>1, and were all negatively associated with both %BF/WHtR. In addition, total sedentary time was positively associated with %BF in girls.

4 DISCUSSION

4.1 Main findings

This study indicates that the total *volume* of sedentary behavior is inconsistently associated with children's adiposity when appropriate adjustments are made. On the other hand, it appears that not all *types* of sedentary behavior are "created equal", with time spent watching television being consistently linked with adiposity. We also found important sex differences, showing that in girls non-screen behaviors such as passive transport may have a protective association against adiposity. In boys, prolonged sedentary bouts may be associated with increased %BF, as may time spent in other screen-based activities – namely, videogames and computer use.

4.2 Previous studies

4.2.1 Volume of sedentary behavior

Total volumes of sedentary time were inconsistently linked with adiposity and we also saw an unexpected negative association with WHtR in boys (versus the expected positive association seen with %BF in girls). This finding is difficult to explain, except that the inconsistency of these results further supports the importance of looking at the *quality* of sedentary behavior in terms of types and patterns, while also adjusting for physical activity as we have done here. Furthermore, our findings mirror those of recent meta-analyses and systematic reviews [3, 4, 6] in children, reporting limited or no evidence of an association between objectively measured total sedentary time and adiposity after MVPA adjustments.

4.2.2 Patterns of sedentary behavior

Time spent in prolonged bouts of sedentary behavior (≥30 min) was positively associated with adiposity in boys, but not in girls. Comparing our findings with previous work is difficult as few studies have been done with children, and there is no consensus around definitions of bouts and breaks in sedentary time. A recent systematic review reported three out of four studies supporting a link between longer sedentary bouts (≥ 5minutes) and increased adiposity [3]. For instance, Carson et al [8] found that sedentary bouts of 5-9 and 10-19 minutes were associated with BMI z-score in children (both sexes) with low MVPA, although they reported no such association with longer sedentary bouts (>20 minutes).

4.2.3 Types of sedentary behavior

Television

Of all the types of sedentary behaviors assessed, television occupied the largest portion of children's time (2.5-3 hours/day). Time spent watching television ranked as the most important correlate of adiposity, having a positive association in girls. In boys, television ranked as slightly less important but still showed positive associations.

Our findings are consistent with prior research. Systematic reviews in 5-17 year olds, [2, 3] confirm that higher television viewing is linked with unfavourable body composition, especially when viewing >2 hours/day (cut-points ranging from 1-4 hours/day [3]). Another systematic review of prospective studies [6] found moderate to strong evidence of a relationship between television and overweight/obesity. Notably, there are far fewer studies that have used more accurate body fat measures, examined television time in isolation from other forms of screen time, and adjusted for physical activity. In fact, of the studies reporting links between body fat and television viewing, we found only one that adjusted for physical activity (finding a persistent relationship) [25]. Furthermore, we are only aware of two other studies [26, 27] which have used DXA to evaluate %BF. One confirmed a longitudinal relationship between watching >2 hours of television and higher %BF three years on [27]. The other study [26] found no such association (in an older sample of 14-17 year old girls).

To date, several mechanisms have been proposed in the literature to explain possible associations between television and obesity. Screen time may displace more active pursuits or late-night screen time may interfere with sleep, which is a known risk factor for obesity [28]. Watching television during meals has also been associated with overweight/obesity in children [29], potentially promoting increased energy/caloric intake through "unmindful" eating [30]. Children are also exposed to advertising of energy-dense foods/beverages that may encourage snacking which has also been linked to overweight among children [31].

Computer

Computer use only ranked as important in boys, exhibiting a positive relationship. Few studies have examined computer use independent of other types of screen time [32, 33]. Despite this, prior literature suggests a positive relationship between computer use and adiposity in *both* sexes, [32, 33] that persists after adjusting for aerobic fitness [32].

Videogames

Boys spent 34 minutes/day longer than girls playing videogames. Thus, it is not surprising that more time playing videogames was associated with higher %BF in boys only. Previous investigations examining relationships between videogames and body fat have reported conflicting findings [26, 34], which may be due to not separating out videogames from other electronic media; also precluding comparisons with our study.

Non-screen sedentary behaviors

Children spent 42-48 minutes/day in passive transport and 51-53 minutes/day eating, with girls spending slightly more time than boys in both of these activities. Unexpectedly, we found that the *more* time girls spent engaged in non-screen sedentary behaviors/passive transport, the *lower* their adiposity. While speculative, this could be a reflection of a more favourable family environment that could be particularly important for girls. For instance, a less chaotic family-life could be conductive to both more non-screen sedentary time (e.g. study, reading, family dinners) and healthier lifestyles. Interestingly, cross-sectional data supports this premise, showing non-screen time to be favourably linked with body composition [3].

Covariates

The present study considered a range of covariates, although only income and total daily energy expenditure (PAL) made a meaningful contribution to adiposity. In boys, PAL ranked as the most important correlate of adiposity (negative association), and in girls it was the second strongest contributor. Since MVPA is a major contributor to PAL, these findings support previous literature which consistently reports inverse associations between physical activity and adiposity [35]. Interestingly, MVPA was not a significant predictor of fatness once overall energy expenditure had been considered.

Of the socio-demographic factors measured, only SES (household income) ranked as important, having an inverse association with adiposity. This finding concurs with prior research that children from families with lower material wealth have a higher risk of obesity [36].

Sex differences

Our study suggests that sex differences may exist when examining relationships between different constructs of sedentary behaviour and adiposity. At this stage, we can only speculate why this may be the case. It may be linked to different use-of-time profiles in certain behaviours; for instance, compared with girls, boys spent substantially more time playing video games. Alternatively, there may be complex interactions with other factors not captured here, or certain sedentary behaviours may be more likely to displace other healthful behaviours in one sex.

4.3 Strengths and limitations

A major strength of this study was the use of a gold standard method, DXA, to estimate adiposity. Furthermore, the combined use of WHtR and DXA reflects both overall and central adiposity. Compared with previous studies, a wider range of sedentary behavior dimensions were captured, using reliable and validated objective and self-report methods. The MARCA is a rigorous self-report tool that incoporates multiple strategies to optimize recall accuracy, and the use of blinded interviewer administration was a further strength. The PLS analysis offered here enables the systematic ranking of factors associated with adiposity, with each factor adjusted for other domains of sedentary behaviors and relevant covariates. To our knowledge, previous studies have not been published using such approaches due to issues with multicollinearity (a limitation overcome by PLS).

There are however some noteworthy limitations – the cross-sectional design limits causal references, and data were not available for energy intake, which could mediate associations between sedentary behavior and adiposity. Furthermore the MARCA apportions time to the main activity being undertaken (not reflecting multi-tasking) so individual activities may be underrepresented, although whether they are sedentary or not should still be captured. As this study examined obese and healthy-weight children, findings may not be generalisable to overweight/underweight children. Furthermore, there is no consensus on how to operationalise patterns of sedentary behavior and alternative methods to those used here may impact findings. Finally, VIPs for certain variables had wide confidence intervals and should be interpreted with caution. The VIP cut-off of 1, while a widely-used rule of thumb, is still a relatively arbitrary point that could be a source of imprecision in terms of variable selection/identification. Further research is also needed to explore educational versus recreational screen use, along with other subsets of screen time (e.g. tablets, social media use) which were not captured here. Compositional analyses using prospective data to explore whether screen time does indeed displace more healthful behaviors would also be of value.

4.4 Conclusion

The methodologies used in this study offer new insight, suggesting that characteristics of sedentary behaviors other than duration may have important links with children's adiposity, and that associations may be sex-specific. Current guidelines do not distinguish between television, videogame and computer use, let alone more recent screen avatars such as iPads, tablets and smartphones. Further investigations of non-screen based sedentary activities, which may actually be protective, are also important. In regards to patterns of sedentary behavior, the association between time spent in a variety of shorter lengths of bouts and obesity is another potentially important area that is still not well understood. Future studies may also benefit by adjusting for energy intake as this could mediate the association between sedentary behavior and weight outcomes.

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Table 1 Descriptive characteristics for demographic, body composition, and use of time variables.

	Boys n= 130 (56%)	Girls n= 104 (44%)	p-value	Total N= 234 (100%)
Demographics				
Age (years) [a]	12.0 (1.2)	11.8 (1.1)	0.60	11.9 (1.2)
Family Income (count) [b]				
Up to $20,000	12 (9%)	4 (4%)	0.12	16 (7%)
$20,001-$40,000	17 (13%)	16 (15%)		33 (14%)
$40, 0001- $60,000	13 (10%)	7 (7%)		20 (9%)
$60,0001-$80,000	21 (16%)	21 (20%)		42 (18%)
$80,001- $100,000	22 (17%)	21 (20%)		43 (18%)
$100,001- $150,000	35 (27%)	18 (17%)		53 (23%)
>$150,000+	10 (8%)	17 (16%)		27 (12%)
Tanner stage (count) [b]				
Level 1 (immature)	28 (22%)	9 (9%)	**0.04**	37 (16%)
Level 2	50 (39%)	38 (37%)		88 (38%)
Level 3	33 (25%)	31 (30%)		64 (27%)
Level 4	15 (12%)	21 (20%)		36(15%)
Level 5 (mature)	4 (3%)	5 (5%)		9(4%)

	Boys n= 130 (56%)	Girls n= 104 (44%)	p-value	Total N= 234 (100%)
Body composition				
% Body Fat [a]	30.2 (13.9)	35.0 (12.0)	**<0.01***	32.3 (13.2)
WHtR [a]	0.5 (0.1)	0.5 (0.1)	0.86	0.5 (0.1)
Sedentary Behavior (min/day)				
Total sedentary time (%) [a, d, e]	51 (8)	52 (6)	0.08	52 (7)
Bouts (%) [a, d, g]	11 (7)	12 (6)	0.19	12 (6)
Television [c, f]	176 (104)	139 (101)	**0.02***	165 (111)
Computer [c, f]	13 (38)	15 (36)	0.30	14 (37)
Videogames [c, f]	30 (65)	1 (23)	**<0.01***	15 (45)
Non-screen time [a, f]	93 (34)	101 (34)	0.07	96 (34)
Eating [a, f]	51 (15)	53 (17)	0.40	52 (16)
Passive transport [a, f]	42 (28)	48 (28)	0.09	45 (28)
Physical Activity				
MVPA [a, d, h] (%)	7 (3)	5 (2)	**<0.01***	6 (3)
PAL [a, f]	1.62 (0.20)	1.53 (0.17)	**<0.01***	1.58 (1.9)

	Boys n= 130 (56%)	Girls n= 104 (44%)	p-value	Total N= 234 (100%)
Sleep				
Sleep duration (average min/day) [a, d]	552 (45)	544 (35)	0.14	549 (41)
Bedtime [a, d, i]	21:50 (0:46)	21:55 (0:45)	0.43	21:53 (0:46)
Wake Time [a, d, i]	7:16 (0:27)	7:16 (0:36)	1.0	7:16 (0:31)

*significant difference between girls and boys are shown in **bold** ($p \leq 0.05$). [a]Presented as mean (standard deviation) and were analysed using the Students' Independent Samples T test. [b]Ordinal data are shown as counts per category (% of total counts), analysed using Chi Square Test (Monte Carlo P value for income and Fisher's Exact P value for Tanner). [c] Shown as median (IQR), analysed using the Exact Mann Whitney U Test with Monte Carlo P values reported. [d] Variable derived from accelerometry. [e] Normalised for wear time (average minutes/day of ≤100 CPM/total wear time) x 100 to express as a percentage, [f] Derived from the Multimedia Activity Recall for Children and Adolescents. [g] Normalised for total sedentary time (average minutes/day in bouts ≥30 min/total sedentary time) x 100 to express as a percentage, [h] Normalised for wear time (average minutes/day of MVPA/total wear time) x 100 to express as a percentage, [i] Bedtime and wake time presented as mean in 24 hour time and (standard deviation) in hour: minutes, but units for statistical analysis were minutes post midnight per day. Abbreviations: WHtR= waist-to-height ratio; min= minutes, MVPA= moderate to vigorous physical activity; PAL= physical activity level.

FIGURE LEGENDS

Figure 1: Variables of importance in projection (VIP) of demographic and use of time variables and body fat percentage (top panel) and waist-to-height ratio (bottom panel) in **boys**. Variables are ranked in order of importance. Variables crossing the dotted line (VIP >1) are highlighted in grey and are considered to make a meaningful contribution. Arrow bars represent the 95% confidence interval, to demonstrate variance but do not represent significance. Positive relationships are indicated with '+' and negative relationships with '-'. Abbreviations: TV= television; PAL= physical activity level; SB= sedentary behavior; MVPA= moderate to vigorous physical activity.

Figure 2: Variables of importance in projection (VIP) of demographic and use of time variables and percent body fat (top panel) and waist-to-height ratio (bottom panel) in **girls**. Variables are ranked in order of importance. Variables crossing the dotted line (VIP >1) are highlighted in grey and are considered to make a meaningful contribution. Arrow bars represent the 95% confidence interval, to demonstrate variance but do not represent significance. Positive relationships are indicated with '+' and negative relationships with '-'. Abbreviations: MVPA= moderate to vigorous physical activity; PAL= physical activity level; TV= television; SB= sedentary behavior.