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Validation of Marshall-D to Monitor Domain-specific Sitting Time among Danish Adults

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Abstract Awareness of the health risks related to high amounts of sitting has increased the need for reliable and valid measures to monitor sitting time. The aim of the present study was to test the reliability and validity of a modified version of the Marshall domain-specific questionnaire (called Marshall-D) to monitor sitting time in large population-based studies. A convenience sample of 122 participants was included. The questionnaire, Marshall-D, considered sitting on weekdays and weekend days during transport, work, leisure screen time and other leisure sitting time. The questionnaire was repeated after two weeks. Sitting time was measured objectively by Axivity worn on the thigh 24 h/day for seven days. Correlations between test and retest and between objective and self-reported measures were assessed by Spearman's rank correlation and Bland Altman plots. Data collection took place in Denmark in 2016. 110 participants had valid data. For test-retest reliability Spearman's rho was 0.68 and 0.35 for weekdays and weekend days. Correlation between self-report and objectively measured total sitting was Spearman's rho=0.44 for weekdays and for weekend days 0.18. In conclusion Marshall-D was found to have acceptable reliability and validity to monitor sitting time during weekdays in population-based surveys. For weekend days reliability and validity levels were unacceptable.

Keywords: *marshall domain-specific questionnaire, workforce sitting questionnaire, sedentary behaviour, reliability, validity*

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1. Introduction

Sedentary behaviour comprises activity with a Metabolic Equivalent (MET)<1.5 in sitting or reclining posture (commonly referred to as sitting time) [1]. Awareness of health risks related to too much sitting has increased the interest in monitoring sedentary behaviour in large population-based studies.

Composite measures of sitting time (i.e. sitting in several domains such as during work or leisure) disclose additional aspects of sitting time compared to single-item measures [2,3,4] and individual domains are found easier to recall than total time spend sitting [5]. Examples of composite measures are the Marshall domain-specific questionnaire and Workforce Sitting Questionnaire (WSQ), both considering daily sitting time in five different domains (travel, work, TV, computer use at home, other leisure activities), but differing in that the Marshall domain-specific questionnaire considers weekday and weekend day, while WSQ considers workday and non-workday.

The two questionnaires have been validated in Britain and Australia among working populations [2,6] and middle-aged [7], however to be used in large population-based studies it is relevant for the question to cover all age groups and modes of labour market attachment.

Additionally, Clemes et al. [2] suggested that concurrent use of TV and computer may affect the validity of the questionnaire if participants are not directed on how to report concurrent use.

Therefore, the present study aimed to modify the Marshall domain-specific questionnaire and WSQ into a measure accommodating both a working and non-working population as well as concurrent screen-based activities, and to test the reliability and validity of this new questionnaire, called Marshall-D, in a diverse population.

2. Methods

2.1. Sitting Time Questionnaire: Marshall-D

The Marshall domain-specific questionnaire was modified considering workday/weekday and screen time. Changes were made through discussions in the project group based on prior experience, existing literature and experience from other researchers. Details on these changes are given below.

Marshall's questionnaire considers weekdays and weekend days while the Workforce Sitting Questionnaire considers workdays and non-workdays. To combine the two, Marshall-D specified that weekdays were workdays (questionnaire text: 'On a weekday/workday') and weekend days were non-workdays (questionnaire text: 'On a weekend day/non-workday'). In this way, people working in the weekend were directed to fill out their workdays in the weekday-column, and people not working at all were directed to divide their days into weekdays and weekend days. The two domains 'watching TV' and 'using a computer at home' were combined into 'screen time during leisure' and the text explained that this included both TV, computer, tablet and smartphone.

<table>
<tr><td colspan="5">During a usual day, how much time do you spend sitting in each of the following situations?
Please consider your total sitting time and divide it on the listed categories</td></tr>
<tr><td></td><td colspan="2">On a weekday /workday</td><td colspan="2">On a weekend day /non-workday</td></tr>
<tr><td></td><td>Hours</td><td>Minutes</td><td>Hours</td><td>Minutes</td></tr>
<tr><td>Transport (e.g. car, bus or train. Do not include cycling)</td><td>|__|__|</td><td>|__|__|</td><td>|__|__|</td><td>|__|__|</td></tr>
<tr><td>Work/school/education (e.g. sitting at a desk or in a meeting)</td><td>|__|__|</td><td>|__|__|</td><td>|__|__|</td><td>|__|__|</td></tr>
<tr><td>Leisure: Screen time (e.g. TV, computer, tablet, smartphone)</td><td>|__|__|</td><td>|__|__|</td><td>|__|__|</td><td>|__|__|</td></tr>
<tr><td>Leisure: Other (e.g. meals, reading, being with others)</td><td>|__|__|</td><td>|__|__|</td><td>|__|__|</td><td>|__|__|</td></tr>
</table>

Figure 1. Marshall-D Questionnaire on Sitting Time

Content validity was assessed through cognitive interviewing, which helps understand the cognitive processes taking place when answering a questionnaire [8]. Twelve interviews were conducted with participants of different sex, age and education, and the results led to small adjustments to the questionnaire. The primary adjustment was that, after the introductory text, an explanation was added, which specified that the total sitting time should be divided on the different domains. This text was added to avoid participants reporting the same periods in multiple domains in case of concurrent activities. The final questionnaire is displayed in Figure 1.

2.2. Study Sample and Recruitment

We aimed to estimate correlation coefficients between 0.4 and 0.7 between self-report and measured sitting time. Using sample size estimation methods described by Walter et al. [9] the required sample size was estimated to 40 people when accounting for a 20% loss to follow up. To be able to stratify on sex, sample size was increased to 120 people.

Recruitment process is described in details elsewhere [10] but in short participants were recruited through several sources, continuously aiming for a balanced distribution regarding sex, age, education and region of Denmark. All participants received written and oral information and signed written informed consent.

The content of the survey did not require registration at the local ethical committee (H-16020894). Data managing procedures were approved by the Danish Data Protection Agency (2015-57-0008). The survey content and procedures were designed according to the Helsinki Declaration [11].

2.3. Questionnaire

The final version of Marshall-D was included in a longer questionnaire, including questions on e.g. sex, education, health and physical activity. Participants answered the questionnaire twice with two weeks in between. Details on the survey is described elsewhere [10].

2.4. Activity Monitor

Sitting time was measured with an Axivity AX3 accelerometer, which is waterproof and records tri-axial acceleration [12]. The accelerometer was set to record at 25 Hz and fastened with allergy friendly tape on the thigh midway between the hip and knee joint. Participants were asked to wear the accelerometer 24 h/day for seven consecutive days, however, they were told to remove it if skin irritation occurred. Participants kept a log during the monitor period recording sleeping and working hours and any irregularities, e.g. non-wear time.

2.5. Data Processing

2.5.1. Questionnaire Data Processing

Hours of sitting were converted into minutes and summed with minutes of sitting. Total sitting time >18 hours was truncated to 18 hours while total sitting >24 hours was categorised as missing. Sitting time on a weekday was summed in three categories: total sitting, sitting at work and sitting during leisure (sum of transport, screen time and other). Sitting time on a weekend day was summed into total sitting time (all four domains).

2.5.2. Activity Monitor Data Processing

Data was processed using Acti4 software specially developed for thigh mounted accelerometers. Acti4 has been validated in different settings and has high sensitivity and specificity to distinguish sitting from standing [13,14,15]. Acti4 compiles total minutes spent in different activities e.g. sitting, standing, walking and cycling. Non-wear time was identified in three ways and discarded with a buffer of 10 minutes before and after: i.) if mentioned in the log; ii.) if detected during data processing; or iii.) if detected by Acti4 (a combination of >60 minutes with no movement immediately preceded by a strong acceleration [14]). Time at work, leisure time and sleep were distinguished using the information recorded in the log. Working hours also included working from home and study-time for students. Participants not working had their days separated into weekdays (Monday–Friday) and weekend days (Saturday–Sunday).

In line with previous studies [10,16], days were only included if they had valid data for at least four hours of work and three hours of leisure for workdays, and at least seven hours of valid data for weekend/non-work days. To be included in the analysis, participants had to have valid data from minimum three days constituting of at least two weekdays and one weekend day.

2.5.3. Final Study Population

A total of 122 participants were enrolled in the study. Of those six (5%) had activity data excluded during data processing e.g. due to technical problems with the device and four (3%) did not have the required number of valid days. One participant did not have valid data in questionnaire 1. In total 111 participants had valid data for analysis of weekdays and 110 for weekend days. Participants having valid activity data did not differ significantly from the total study population regarding age, sex and education (data not shown).

2.6. Statistical Analysis

Correlations between test-retest and between objective and self-reported sitting were assessed by Spearman's rank correlation coefficient (Spearman's rho). Based on findings in similar studies acceptable reliability required Spearman's rho ≥0.50, while acceptable validity required Spearman's rho≥0.30 [17,18]. Additionally, Bland-Altman plots were used to describe validity. Statistical analyses were performed in Stata 14.1.

Sensitivity analyses repeated main analyses but using a requirement of 10 h/day of valid data (instead of 7 h/day).

3. Results

3.1. Participant Characteristics

Participants were 50% women, mean age was 43 years and there was an equal distribution on educational level (Table 1). Median weartime for Axivity was five weekdays and two weekend days.

3.2. Test-retest Reliability

Correlations between measures of sitting time as assessed by Marshall-D two weeks apart were on weekdays for total sitting time Spearmans Rho 0.68, for sitting time at work 0.83, and for sitting during leisure 0.63. For weekend days correlation for total sitting time was 0.35. Correlations for the individual domains are displayed in Table 2. All correlations were higher for women (Spearmans Rho 0.47–0.90) than for men (Spearmans Rho 0.20–0.77) (Table A in supplementary material).

3.3. Criterion Validity

Median total sitting time on weekdays was 615 min/day self-reported (Interquartile Range, IQR 450;720) and 613 min/day objectively measured (IQR 535;677)), total sitting time on weekend days was 510 min/day self-reported (IQR 390;615) and 530 min/day objectively measured (IQR 452;636)) (Table 3).

The highest correlation between self-reported and objectively measured sitting time was found for sitting during working hours on a workday (Spearmans Rho 0.54). For leisure time sitting on workdays Spearmans Rho was 0.48 and for total sitting on workdays 0.44. For total sitting on weekend days Spearmans Rho was 0.18 (Table 3). Results from Bland-Altman plots (Table 3) showed mean differences close to 0 (-29 to 27 min). Limits of agreement were narrowest for sitting time at work (-227;282) and widest for sitting on weekend days (-490;450). For workdays, correlations between self-reported and objectively measured sitting were higher for women (Spearmans Rho 0.50–0.59) than men (Spearmans Rho 0.34-0.52), while for weekends, men had higher correlations than women, (Spearmans Rho 0.21 and 0.16) (Table B in supplementary material).

Table 1. Participants Characteristics, n=122

Questionnaire data	N (%)
Sex, men	61 (50)
Age, mean (min;max)	43 (16;85)
Educational level*	
Low	44 (36)
Medium	45 (37)
High	32 (26)
Labour market attachment	
Employed	70 (57)
Student	27 (22)
Unemployed/retired	25 (21)
BMI >25, kg/m2	45 (37)
Self-rated health; Less good/bad	7 (6)
Prolonged illness (lasting >6 months)**	37 (30)
Functional limitations***	51 (42)
Inactive during leisure time	12 (10)

*Low: basic school, vocational school or upper secondary. Medium: 3-4 years of higher education e.g. teacher, nurse, bachelor degree. High: >4 years of higher education e.g. doctor, engineer, master's degree.
**Includes any illness, disease or disability lasting more than 6 months
***To some extent or very much experiencing any functional limitation because of health problems during the past 6 months.

Table 2. Test-retest Reliability

	Spearmans rho (ρ)	
	Weekdays	Weekend days
Total	0.68	0.35
Work	0.83	-
Leisure	0.63	-
Sub-domains		
Transport	0.78	0.53
Screen	0.59	0.53
Other	0.44	0.47

Correlation between answers in questionnaire one and two (14 days apart). n=111 for weekdays and n=110 for weekend days.

Table 3. Comparison Between Self-reported and Objectively Measured Sitting time

		n	Self-reported Median (IQR*)	Objectively measured Median (IQR*)	Spearmans Rho	Mean difference** (min/day)	Lower LOA*** (min)	Upper LOA*** (min)
Weekday	Total	111	615 (450;720)	613 (535;677)	0.44	3	-369	376
	Work	88	360 (180;443)	304 (219;352)	0.54	27	-227	282
	Leisure	111	300 (240;420)	339 (271;441)	0.48	-29	-343	285
Weekend day	Total	110	510 (390;615)	530 (452;636)	0.18	-20	-490	450

Median self-reported and objectively measured sitting time (min/day) and Spearmans Rho. Bland-Altman Statistics: mean difference between self-reported and objectively measured sitting time, lower and upper limits of agreement. Denmark 2016.
*Interquartile Range (IQR):25;75.
**Mean difference – self-reported - objectively measured sitting time
***LOA – limits of agreement (CI 95%).

3.4. Sensitivity Analyses

Sensitivity analyses were carried out using a requirement of 10 h/day of valid data, which did not change the above results.

4. Discussion

The present study assessed reliability and validity of Marshall-D, a questionnaire to measure sitting time in population-based studies. Test-retest reliability (Spearman's rho 0.35-0.84) yielded satisfying results as compared to the predefined acceptable levels [17,18,19].

Concerning validity, results were satisfying for sitting time on weekdays in total and during work and leisure separately (Spearmans Rho 0.44–0.54), however for weekend days, the validity for total sitting time was unacceptable (Spearmans Rho 0.18).

Compared to other studies, Marshall-D had similar reliability and validity, and similar conclusions regarding acceptable results for weekdays, but not weekend days [2,7]. Chau et al. [20] found satisfactory results for both weekday and weekend days, though results were only just acceptable (r=0.29–0.34 for weekdays and r=0.18–0.23 for weekend days).

Levels of mean differences of -29 to 27 min/day in the present study were comparable to other studies (-64 to 11 min/day in Marshal et al. [7], -4.2 to -13.7 min/day in Clemes et al. [2] and 2 to 45 min/day in Chau et al. [20]). Limits of agreement were also like the ones reported by others [2,7,20].

Altogether, Marshall-D seems to perform at the same level as similar questionnaires, but with the inclusion of weekday/workday and weekend day/weekday it is more suitable for use in mixed populations of workers and non-workers. In addition, by combining TV and computer use into screen-time the questionnaire accommodates concurrent use of devices.

4.1. Strengths and Limitations

A main strength of the study was the objective measurement method, an accelerometer placed on the thigh, which has good discrimination between sitting and standing. Additionally, the general wear time was high (median of five weekdays and two weekend days) resulting in high quality data. The number of participants was another strength, as it allowed for stratified analyses.

The main limitation was that participants were sampled using a convenience approach. A wide distribution was sought during the recruitment process and the study population constituted people of different sex, age and education. However, questionnaire data analyses of the final study population showed that, compared to the general population [21], participants had better self-rated health, and were better educated and more physically active. This could influence generalizability of the results, as persons, who are better educated and of better health, might be better at self-reporting sitting time than the general population because they are more concerned about their health.

Marshall-D was to developed to monitor sitting time in large population-based surveys, thus, before using Marshall-D for individual feedback or intervention studies requiring higher precision, further studies are needed.

5. Conclusions

Marshall-D was developed from Marshall domain-specific questionnaire, adjusted by adding elements from the Workforce Sitting Questionnaire, and by combining TV-time and computer time into screen-time.

Marshall-D was found to have acceptable reliability and validity to monitor sitting time during weekdays in population-based surveys. For weekend days, reliability and validity levels were not acceptable.

Based on this study, we would thus recommend Marshall-D to be used to monitor weekday sitting in population surveys. However, we suggest leaving out the weekend-part of the questionnaire.

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Availability of data and material: The dataset used during the current study is available from the corresponding author on reasonable request.

Authors' contributions: ID and JT designed and lead the study. ID collected and analysed the data in close cooperation with JT. ID drafted the manuscript based on the original research. JT contributed to the editing of the manuscript and all authors have read and approved the final version of the manuscript.

Abbreviations

MET: Metabolic Equivalent; WSQ: Workforce Sitting Questionnaire; IQR: Interquartile Range; ICC: Intraclass Correlation Coefficient; LOA: Limits of Agreement

Supplementary Material

Table A. Test-retest reliability. Correlation between answers in questionnaire one and two (14 days apart). N=111 for weekdays and n=110 for weekend days.

Table B: Comparison between self-report and objectively measured sitting time (min/day)

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Supplementary Material

Table A. Test-retest reliability. Correlation between answers in questionnaire one and two (14 days apart). n=111 for weekdays and n=110 for weekend days

	Spearmans rho (ρ)			
	Weekdays		**Weekend days**	
	Men	**Women**	**Men**	**Women**
Total	**0.54**	**0.81**	**0.20**	**0.49**
Work	0.77	0.90	-	-
Leisure	0.45	0.79	-	-
Sub-domains				
Transport	0.66	0.84	0.35	0.67
Screen	0.50	0.68	0.41	0.63
Other	0.25	0.59	0.42	0.47

Table B. Comparison between self-report and objectively measured sitting time (min/day)

		n	Mean difference* (min/day)		Lower LOA** (min)		Upper LOA** (min)		Spearmans Rho	
			Men	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
Weekday	Total	111	-17	-22	-450	-327	417	284	0.34	0.56
	Work	88	9	-43	-273	-270	291	184	0.52	0.59
	Leisure	111	-39	20	-404	-240	326	280	0.43	0.50
Weekend day	Total	110	-79	-35	-550	-482	391	412	0.21	0.16

*Mean difference – self-reported - objectively measured sitting time
**LOA – limits of agreement (CI 95 %).