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Original Article

Daily activity Borg scale (DABS): using the Borg's RPE scale for assessing the level of daily physical activity

BOAZ SHULRUF[1,2], MIRI SHACHAF[3], ELLA SHOVAL[4]
[1]University of New South Wales, Sydney, AUSTRALIA
[2]University of Auckland, Auckland, NEW ZEALAND
[3]Givat Washington Academic College of Education, Givat Washington, ISRAEL
[4]The Academic College at Wingate, Netanya, ISRAEL

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Abstract
Problem statement and approach: Levels of daily physical activity impact health and well-being, yet measuring daily activity of large populations is challenging. These challenges include, but are not limited to: the definition of the activity and its intensity, the reliability and validity of self-report questionnaires, and the limitations of mobile and wearable devices and applications. Such challenges are increased when undertaking population-based studies or when there is a need to retrospectively assess daily physical activity. The current study introduces a new tool, the Daily Activity Borg Scale (DABS), which is based on Borg's ratings of perceived exertion, and uses participants' reports of their perceived exertion in the past 24 hours, by the hour, on a 1-9 exertion scale. This study assesses the feasibility and validity of the DABS. Materials and methods: Two hundred and ninety-eight participants (105; 35.2% males) took part in this study. Each participant reported his/her perceived exertion of the past 24 hours (hour by hour). These perceived exertion reports were then compared to reports of actual physical activities of the participants, as well as the change in perceived exertion during the previous 24 hours. Results: Taking <10 minutes to fill out, the DABS is a handy self-reporting tool for assessing daily physical activity intensity levels. The DABS provided the expected perceived level of activity throughout the 24 hours of the day and was significantly associated ($p<.001$) with reports of actual physical activities. Discussion: The DABS provides a simple yet robust measure of daily physical activity, by utilising the well-established Borg ratings of perceived exertion (RPE) scale to record the most recent daily physical activity. The results demonstrated strong associations between the perceived exertion and the type of physical activity reported, as well as an alignment between the daily hour-by-hour changes in exertion with the expected daily activity. Conclusions: The DABS was found to be a valid and feasible tool for assessing daily physical activity for large-scale populations.
Keywords: self-report questionnaire; perceived exertion; validity; feasibility

Introduction

The level of daily physical activity is known to have an impact on general health and well-being measures (Budzynski-Seymour et al., 2020; Gacek et al., 2020; Pavlova et al., 2015; Wang & Boros, 2019), including but not limited to well-functioning cardiovascular systems,(Lacombe et al., 2019), mental health (Pavlova et al., 2015), protection of skeletal muscle from aging,(Ubaida-Mohien et al., 2019) influencing physical function,(Edholm et al., 2019) a declining cancer risk,(Wang et al., 2019) and reducing the risk of cognitive decline.(David & Parasuraman, 2019).

One of the challenges scientists and practitioners commonly encounter is measuring the daily activity level. The literature has introduced a number of daily activity scales (DAS), yet each has advantages as well as shortcomings, for example the determination of what physical activity constitutes. Does physical activity relate to exercise only or also to normal daily life activity? How are different activities classified? How do we account for a seasonal or a one-off activity? To address these challenges, a number of DAS have been introduced.(Ainsworth et al., 2000; Doma et al., 2019; Liu et al., 2020) The most commonly used methods used in DAS are self-report questionnaires and the use of electronic devices which detect and record body movements (Skender et al., 2016). In recent years sophisticated mobile phone devices and applications have been introduced, offering accuracy levels ranging between 50% -100%.(Pedišić & Bauman, 2015) Although these advanced technological instruments provide relatively accurate measurements of physical activity, they fall short on detecting retrospective activity as well as being subjected to time wearing time which may bias the data unless used 24/7 (Pedišić & Bauman, 2015). For example, when a patient sees a clinician or an exercise physiology

Corresponding Author: BOAZ SHULRUF, E-mail: b.shulruf@unsw.edu.au

expert and wishes to report about his/her daily activity, the electronic instruments are useless unless they have been pre-installed before that appointment. Another shortcoming of device-based measurement of physical activity is that it cannot be used for large-scale surveys, since accuracy and availability of devices and applications vary across populations (e.g., some economically disadvantaged groups may not have access to such devices). Moreover, most wearable devices and mobile phones cannot be used during water activities such as swimming or bathing. Altogether, these limitations may compromise the quality of the data obtained.(Brodie et al., 2018)

Consequently, the use of questionnaires for measuring daily physical activity is still valuable, particularly when simple, short, and valid scales are used.(Skender et al., 2016) The common type of questionnaire used for measuring daily physical activity is a physical daily log which asks the participant to report which activities they experienced and how long they lasted (Doma et al., 2019). Although calling for quite detailed information, such questionnaires specify particular activities (e.g., walking, running, etc.) and have only a rudimentary scale for measuring the level of intensity.(Curtis et al., 2020; Doma et al., 2019)

One of the most established self-report measures for intensity of activity is the Borg ratings of perceived exertion (RPE) scale (henceforth the Borg scale),(Borg & Linderholm, 1967) which is based on the high correlations identified between the perceived exertion and heart and respiration rates. In brief, the Borg scale uses a 15-grade scale (between 6 to 20) to describe the perceived exertion, and starts with 7 ('Very very light') up to 19 ('Very very hard').

The scale values, which ranged from 6 to 20, are used to denote heart rates ranging from 60-200 heartbeats per minute.(Borg, 1982) Nonetheless, despite the well-established evidence supporting its validity, the Borg scale has only been used for reporting current exertion and not for reporting retrospective activity.

To enable the utilisation of the Borg RPE for assessing daily physical activity in a large population, the Daily Activity Borg Scale (DABS) was devised, which asks participants to report the level of perceived exertion of their activity in the past 24 hours, by the hour. A detailed description of the DABS is provided in the Method section below.

The current study investigates the feasibility, utility, and validity of using the Borg scale for population-wide surveys to measure the level of daily physical activity.

Material & methods

Participants

Potential participants were approached by a member of the research team in public places such as various workplaces, tertiary and secondary education campuses, and community centres. Potential participants were asked to fill out the questionnaire. They were encouraged to take additional questionnaires and circulate them among their friends and family, and then to deliver these back to the researcher by dropping off the completed forms at a designated place.

Tools

The DABS (Appendix 1) is based on the Borg perceived exertion scale.(Borg, 1982) Respondents are asked to rate the level of their physical activity from 1=no exertion at all to 9=maximum exertion for every hour in the previous day – overall 24 hours. The Borg scale was modified to a 1-9 exertion scale based on a pilot study which found that the 6-20 scores would be too difficult for the respondents to provide, particularly since they were requested to provide 24 responses (one per hour).

To estimate the validity of the DABS, respondents were asked to report the extent to which they participate in different levels of activity (do not do; do below the desirable level; do at the desirable level; do above the desirable level). Respondents also provided their basic demographic characteristics.

The snowball sampling method (Marcus et al., 2017) was used to recruit participants for this study. This sampling method was chosen since it requires minimum resources for recruiting from diverse populations, and also because the objective of the study was limited to assessing the DABS validity and feasibility, rather than reporting daily activity of a particular population – which may have required a more representative sampling frame.

Statistical analysis

Validating the DABS was done through a number of analyses. The first analysis included graphical presentation of the perceived exertion along the 24 hours of the day. The second analysis, which utilises Univariate analysis, estimated the association between reports on high-intensity physical activity and the daily physical activity reported (do not do; do below the desirable level; do at the desirable level; do above the desirable level). For reasons of simplicity and clarity, the hours reported indicate the time the hour started, i.e., 7 a.m. means 7-8 a.m. In the figures, hours are reported as 00-24; whereas in the text the hours are reported as 00-12, with an indication of a.m. and p.m.

Ethical considerations

The leading institute of this research, Givat Washington Academic College of Education, did not require ethics approval for such research at the time the data were collected (2018-2019). Participants' consent was deemed by responding to the questionnaire since the researchers had no power relationships with any of the potential and actual participants.

Results

Overall, 298 participants took part in this study. Among these were 105(35.2%) males and 174 (58.4%) females; 19(6.4%) did not report gender. Daily activity was reported across all days in the week, however most of the activity reported was for Tuesday (n=121, 40.6%) followed by Wednesday (n=70, 23.5%); Saturday was day with the least activity reported (n=8, 2.7%). Across all reports there were relatively little missing data, as 6731 perceived activities per hour were reported in the data, accounting for a 94.1% response rate.

The initial results (Figure 1) demonstrate that the DABS provided the expected perceived level of activity throughout the 24 hours of the day, for both males and females. In particular, the difference between night (11p.m.-6a.m.) and day (6a.m.-11p.m.) is very significant (95%CI's not overlapping). An elevated level of activity was also observed in the evening (5p.m.-9p.m.), which is normally after work time.

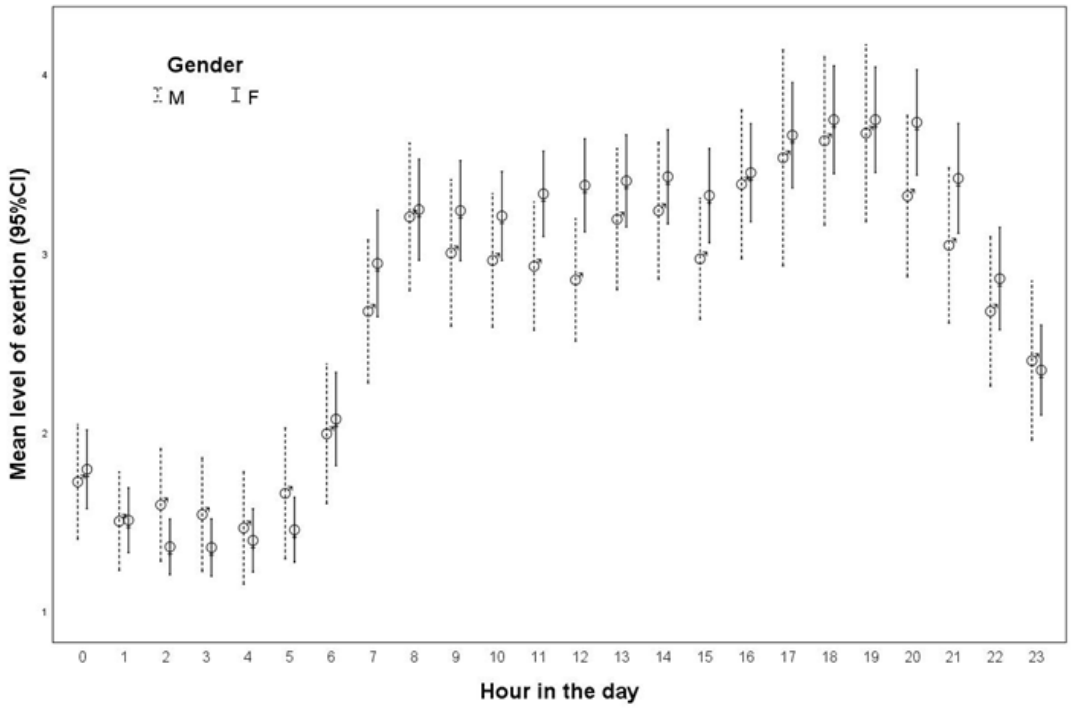

Figure 1 Perceived exertion by hour and by gender

The next analysis compares four subgroups of participants, categorised by their reports of undertaking high-intensity activity (not at all; less then desirable; as desirable; more than desirable). Looking at DABS scores by time for the high-intensity activity group (Figure 2, Table 1), it is demonstrated that those who undertook high-intensity activity beyond the desirable level reported high intensity early in the morning (7a.m.-9a.m.) and in the evening (5p.m.-7p.m.). Their DABS scores in those hours are also higher than all other groups ($p<.05$; $p=.06$ at 5p.m.; see Table 1), yet during working hours (9a.m.-4p.m.) and at night (11p.m.-7a.m.), the DABS scores of all groups were similar.

Table 1 Univariate analysis: Association between the "high-intensity activity group" and DABS scores by time of the day

Time		Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	3.522	3	1.174	.565	.639
	Within groups	552.852	266	2.078		
	Total	556.374	269			
1	Between groups	1.808	3	.603	.423	.737
	Within groups	374.919	263	1.426		
	Total	376.727	266			
2	Between groups	1.604	3	.535	.385	.764
	Within groups	370.440	267	1.387		
	Total	372.044	270			
3	Between groups	.221	3	.074	.053	.984
	Within groups	370.164	266	1.392		
	Total	370.385	269			

	Between groups	.416	3	.139	.094	.963
4	Within groups	393.902	267	1.475		
	Total	394.317	270			
	Between groups	9.377	3	3.126	1.716	.164
5	Within groups	486.350	267	1.822		
	Total	495.727	270			
	Between groups	7.189	3	2.396	.826	.481
6	Within groups	774.811	267	2.902		
	Total	782.000	270			
	Between groups	56.933	3	18.978	5.077	**.002**
7	Within groups	1027.998	275	3.738		
	Total	1084.932	278			
	Between groups	33.042	3	11.014	2.893	**.036**
8	Within groups	1058.437	278	3.807		
	Total	1091.479	281			
	Between groups	42.412	3	14.137	3.906	**.009**
9	Within groups	998.959	276	3.619		
	Total	1041.371	279			
	Between groups	2.886	3	.962	.316	.814
10	Within groups	831.483	273	3.046		
	Total	834.368	276			
	Between groups	3.767	3	1.256	.440	.724
11	Within groups	781.129	274	2.851		
	Total	784.896	277			
	Between groups	1.342	3	.447	.148	.931
12	Within groups	816.380	270	3.024		
	Total	817.723	273			
	Between groups	3.439	3	1.146	.359	.783
13	Within groups	855.763	268	3.193		
	Total	859.202	271			
	Between groups	9.266	3	3.089	.980	.403
14	Within groups	853.956	271	3.151		
	Total	863.222	274			
	Between groups	5.498	3	1.833	.617	.605
15	Within groups	802.010	270	2.970		
	Total	807.507	273			
	Between groups	9.992	3	3.331	.936	.424
16	Within groups	950.053	267	3.558		
	Total	960.044	270			
	Between groups	29.208	3	9.736	2.501	.060
17	Within groups	1046.997	269	3.892		
	Total	1076.205	272			
	Between groups	45.163	3	15.054	3.535	**.015**
18	Within groups	1149.757	270	4.258		
	Total	1194.920	273			
	Between groups	42.822	3	14.274	3.262	**.022**
19	Within groups	1185.855	271	4.376		
	Total	1228.676	274			
	Between groups	27.901	3	9.300	2.296	.078
20	Within groups	1093.530	270	4.050		
	Total	1121.431	273			
	Between groups	25.041	3	8.347	2.043	.108
21	Within groups	1102.974	270	4.085		
	Total	1128.015	273			
	Between groups	13.597	3	4.532	1.250	.292
22	Within groups	967.812	267	3.625		
	Total	981.410	270			
	Between groups	9.194	3	3.065	.948	.418
23	Within groups	865.979	268	3.231		
	Total	875.173	271			

In addition, ANOVA was used to compare the highest DABS score reported across all high-intensity activity groups (1=do not do; 2= do less than desirable; 3= do as desirable; 4= do more than desirable). The results (Figure 3) demonstrate that there was a significant difference between the four subgroups ($p<.001$).

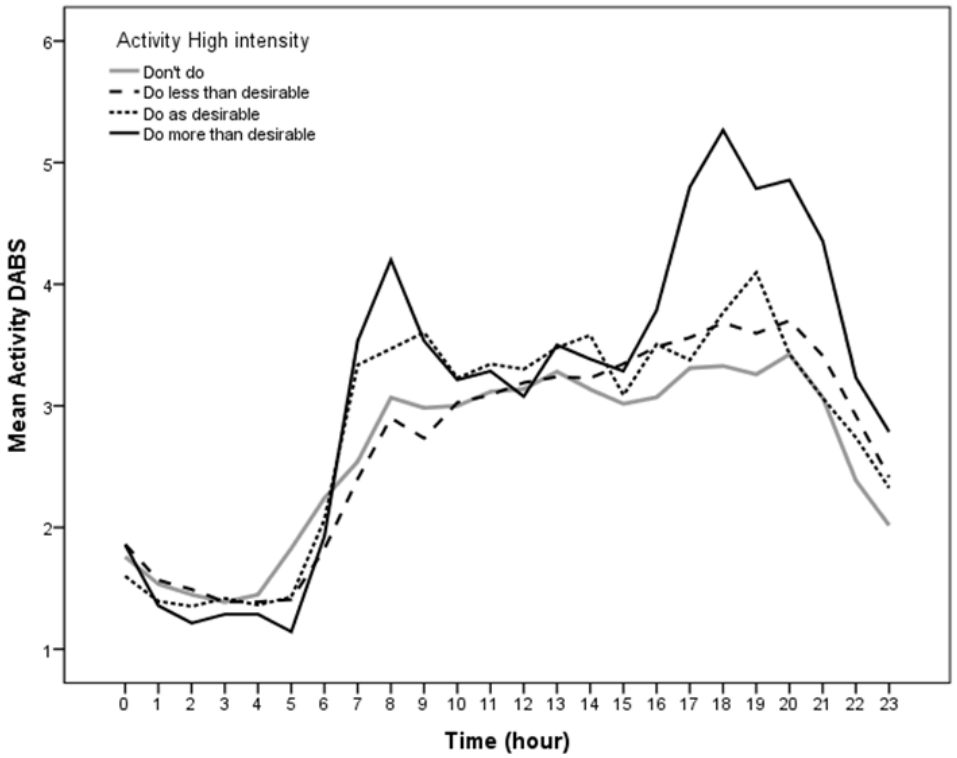

Figure 2 DABS score by time in the high-intensity activity group

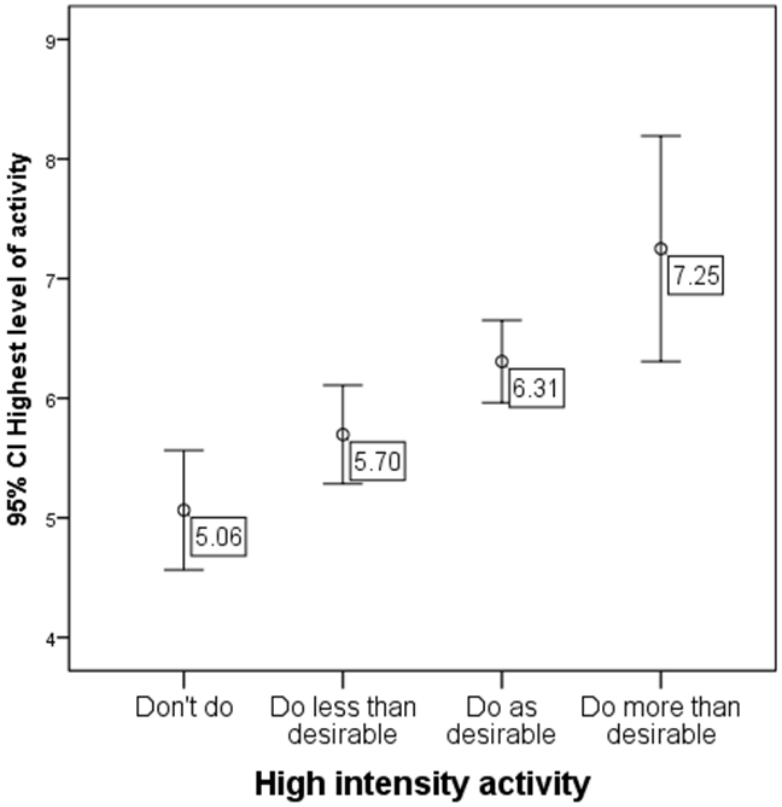

Figure 3 Highest DABS score by self-report of highest intensity undertaken

Discussion

The main objective of this study was to assess the feasibility and validity of the Daily Activity Borg Scale (DABS). The DABS is based on the Borg ratings of perceived exertion (RPE) scale, which has been widely used and was found to be highly correlated with heart rate, blood lactate, oxygen intake, and respiration rate.(Borg, 1982; Borg & Linderholm, 1967) Thus the DABS meets the face validity criterion, which is an essential but sufficient criterion for validity.

The results demonstrate that the DABS is an easy self-reporting tool for physical activity intensity level, as the questionnaire takes less than ten minutes to fill it out. In addition, it demonstrated a low missing data rate (5.9% missing data), suggesting that respondents were able to recall most of the their physical activity from the previous day. The level of accuracy of their reports (i.e., against objective measures taken by devices attached to the respondents) was not assessed in this study, yet it was previously reported that most participants in a population-based daily activity survey provided reliable answers with 60%-79% agreement for repeated self reports (Brown et al., 2004; Ekblom et al., 2015; Weston et al., 1997). The main question, therefore, is related to the validity of the DABS.

The validity of the newly developed Daily Activity Borg Scale (DABS) was assessed by measures of internal and external validity (Avellar et al., 2016; Craike et al., 2017) applicable to population-based tools. This means assessing the association between DABS scores with alternative reports of intensity of activity, as well as assessing the DABS scores against the expected level of activity during 24 hours of the day and across genders.
No significant difference in DABS scores between genders was observed across the 24 hours reported (Figure 1). This is as expected, since no evidence was provided in the literature that males and females perceive physical activity differently. DABS scores provided a very clear daily pattern of activity, which was expected: Low scores at night; two spikes of higher activity early in the morning and in the evening, but only for those reporting being active at or beyond the desirable level; and, no significant difference across groups between 9a.m. to 4p.m., which is the normal working time (Figure 2). This pattern of activity is similar to patterns of daily activity identified elsewhere (Garriguet & Colley, 2012; Jansen et al., 2018). It is also noteworthy that in the current study, as well as in the Canadian study, there was a trend of an increased level of intensity during the working hours. There is no reason to believe – and there is no evidence to suggest – that in Israel and Canada the patterns are different. Nonetheless, future research should look at comparisons between populations, either defined by country, age, or any other characteristic of interest.

Figure 2 demonstrates that the DABS is sufficiently sensitive to distinguish between groups of people classified by their level of activity. The groups that reported undertaking no or below the desirable high-intensity activity demonstrated a steady increase in intensity from 8a.m. to 8p.m., which is in line with the general population elsewhere (Jansen et al., 2018). In contrast, the groups reporting high intensity at or above the desirable levels demonstrated the same trend during work time (9a.m.-4p.m.), as well as significant peaks in level of activity just before and just after the normal working hours (Figure 2). These results add support to the validity of DABS, as they show that during working hours there are no differences between the four groups, but that differences appear only at times when physical activity is most likely to take place. The association between the activity group and the maximum DABS score is presented in Figure 3. All these findings strongly support the validity of DABS.

This study may have some limitations. The most important one is the lack of a direct measure of physical activity, such as a wearable device, which would provide an accurate reference to assess the validity of the DABS. Although desirable, such a procedure was not feasible due to lack of resources. Future research may benefit from such a comparison, and it is recommended. However, this limitation further emphasises the importance of the availability of tools such as the DABS, which are simple, require minimal resources, and can be implemented in a large population.
The other obvious limitation is that this study took place in only one country (Israel). Although no evidence is available to suggest that the validity and utility of such a tool would be different in a different country or culture, it is always better to undertake multisite research when attempting to demonstrate the generalisability of the findings across different environments or contexts. We plan to undertake such an international research in the near future.

Conclusions

The DABS is a readily available tool for assessing daily physical activity, which could be used both at the individual and large-scale population levels. The DABS enables health practitioners to obtain a reliable estimate of patients' daily physical activity at no cost, by asking them to fill out the form just prior to their appointment. This may improve the quality of the initial assessment of the patient's physical condition. For health researchers, the DABS may be used to compare the physical activity levels of different populations at a lower cost. It may be used by health researchers and epidemiologists to generate meaningful research for improving peoples' lifestyle, well-being, and health.

Overall, the DABS appears to be a valid and feasible tool for measuring daily physical activity. Nonetheless, it is important to note that the DABS should be used mostly as a population-based tool for assessing daily physical activity, rather than a tool aiming to provide an accurate and detailed measure of

individuals' physical activity level(Overstreet et al., 2016). The advantage of the DABS over most of the other tools is that it provides information on perceived exertion, rather than asking participants about prescribed activity and then indirectly estimating the level of exertion. The DABS is also sensitive to the time of the day, and covers 24 hours at one-hour intervals. This level of resolution may be useful for identifying patterns of daily activity in more detail. It is therefore recommended that population-based research concerning daily physical activity use the DABS in combination with other tools, since using more than one may provide much more detailed information than using each of them individually.

Conflicts of interest

The authors report no conflicts of interest

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Appendices

Appendix 1: Daily Activity Borg Scale (DABS)

For each hour in the day, please circle the highest level of physical activity exertion (a number between 1= no effort at all to 9= maximum difficulty) you experiences during the last 24 hours starting at 7am yesterday morning. If you experienced different levels of exertion within particular hour (for example, if you watched TV from 9:00pm to 9:30pm and went out for jogging from 9:30pm), mark the highest level of exertion you experienced between 9:00pm to 10pm.

	Level of exertion								
Hour	**1= no effort at all**	**2=extremely easy**	**3=very easy**	**4=easy**	**5=slightly difficult**	**6=difficult**	**7= very difficult**	**8= extremely difficult**	**9= maximum difficulty**
7:00 - 8:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
8:00 - 9:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
9:00 - 10:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
10:00 - 11:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
11:00 - 12:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
12:00 - 13:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
13:00 - 14:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
14:00 - 15:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
15:00 - 16:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
16:00 - 17:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
17:00 - 18:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
18:00 - 19:00	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

19:00 - 20:00	1	2	3	4	5	6	7	8	9
20:00 - 21:00	1	2	3	4	5	6	7	8	9
21:00 - 22:00	1	2	3	4	5	6	7	8	9
22:00 - 23:00	1	2	3	4	5	6	7	8	9
23:00 - 0:00	1	2	3	4	5	6	7	8	9
0:00 - 1:00	1	2	3	4	5	6	7	8	9
1:00 - 2:00	1	2	3	4	5	6	7	8	9
2:00 - 3:00	1	2	3	4	5	6	7	8	9
3:00 - 4:00	1	2	3	4	5	6	7	8	9
4:00 - 5:00	1	2	3	4	5	6	7	8	9
5:00 - 6:00	1	2	3	4	5	6	7	8	9
6:00 - 7:00	1	2	3	4	5	6	7	8	9