Brief article

Monitoring sedentary patterns in office employees: validity of an m-health tool (Walk@Work-App) for occupational health

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A B S T R A C T

Objective: This study validated the Walk@Work-Application (W@W-App) for measuring occupational sitting and stepping.

Methods: The W@W-App was installed on the smartphones of office-based employees (n = 17; 10 women; 26 ± 3 years). A prescribed 1-hour laboratory protocol plus two continuous hours of occupational free-living activities were performed. Intra-class correlation coefficients (ICC) compared mean differences of sitting time and step count measurements between the W@W-App and criterion measures (ActivPAL3TM and SW200Yamax Digi-Walker).

Results: During the protocol, agreement between self-paced walking (ICC = 0.85) and active working tasks step counts (ICC = 0.80) was good. The smallest median difference was for sitting time (1.5 seconds). During free-living conditions, sitting time (ICC = 0.99) and stepping (ICC = 0.92) showed excellent agreement, with a difference of 0.5 minutes and 18 steps respectively.

Conclusions: The W@W-App provided valid measures for monitoring occupational sedentary patterns in real life conditions; a key issue for increasing awareness and changing occupational sedentariness.

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Monitorización de patrones sedentarios en oficinistas: validación de una aplicación móvil (Walk@Work-App) en salud laboral

R E S U M E N

Objetivo: Validar la aplicación móvil Walk@Work (W@W-App) para monitorear los patrones de actividad y sedentarismo en el trabajo.

Método: W@W-App se instaló en teléfonos móviles de oficinistas (n = 17; 10 mujeres; 26 ± 3 años). El tiempo sentado y el número de pasos se midieron mediante un test de laboratorio y bajo condiciones habituales. Las diferencias entre W@W-App y las medidas de referencia (ActivPAL3TM y SW200Yamax Digi-Walker) se compararon mediante coeficientes de correlación intraclase (CCI).

Resultados: En el test de laboratorio, los valores de correlación fueron buenos en los pasos realizados a baja intensidad (CCI = 0,85-0,80). La menor diferencia de mediana fue para el tiempo sentado (1,5 segundos). En condiciones habituales, el tiempo sentado (CCI = 0,99) y los pasos (CCI = 0,92) mostraron valores de correlación excelentes, con una diferencia de 0,5 minutos y 18 pasos.

Conclusiones: W@W-App proporciona medidas válidas para la monitorización de patrones sedentarios en el trabajo: aspecto clave para modificar el sedentarismo en las oficinas.

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Introduction

High volumes of occupational sitting have been associated with an increased risk of cardiovascular disease, type 2 diabetes and musculoskeletal disorders. Thus, reducing sedentary behaviour in office-based work environments has become an occupational behavioural risk that needs to be addressed.1
Introducing smartphone applications (Apps) can support technology-based behaviour change; contributing to maximize the effectiveness of workplace-based programs to reduce occupational sitting.\(^4\) Smartphones are not only a normal part of daily life—used by more than 3.6 billion individuals worldwide\(^1\) but Apps enable users to measure and self-monitor health behaviours in real time. This contributes to recognizing sitting time patterns and increasing awareness,\(^5\) key issues for successfully engaging in “occupational sitting reduction” programs.\(^6\)

App measurements for physical activity have mainly focused on step counts and moderate-to-vigorous physical activity (MVPA) rather than sedentary behaviour.\(^7\) Such Apps gather information from the native sensors of smartphones (Accupedo, Runtastic, Moves, PacerWorks or Tayutau)\(^8\) or from external consumer-based physical activity tracking devices, mainly located on the wrist or waist area (e.g. Fitbit, NickFuelBand or JawboneUp).\(^8\) While the validity of Apps for step counts and MVPA has been reported as moderate to good, validity for sitting time measures is less clear.\(^4\) App measurements—especially for postural classification—vary considerably based on the device location (hip, waist, wrist or upper arm);\(^9\) with current Apps finding it difficult to offer valid measurements for sitting and standing.\(^10\)

Based on the need to identify occupational sedentary patterns in real life conditions within workplace health promotion programs—a key determinant for changing sedentary behaviour—\(^6\) this study aimed to assess the validity of the Walk@Work-App (W@W-App) for measuring occupational sitting time and stepping on Spanish office employees’ own personal smartphones.

### Methods

A convenience sample of Spanish office administrative workers from the University of Vic-Central University of Catalonia, was recruited (April 2015) via inclusion criteria were: having a smartphone with a hardware Android version >4.0, and being able to get up from a chair, perform moderate intensity walking and use the stairs. The study was approved by the University’s institutional review board and volunteers signed a written informed consent.

Participants used their own smartphones with the W@W-App installed, placed in a pouch attached at the right belt side (W@W-App pouch) (Figure 1). The pouch was developed to locate the smartphone sensors in participants’ mid-to-front point of the thigh (near the centre of mass), the best position to avoid postural measurement errors for sitting time, (and to replicate positioning of the criterion measure ActivPALTM). The W@W-App assessed time spent sitting and ambulatory activity in steps. The net external forces acting on the smartphones were detected by the mobile phone accelerometer (X, Y, and Z axes), which was configured using SENSOR_DELAY_GAME at a 25-27 Hz rate. The forward acceleration signals registered step counts. For sitting time a 30-degree tilt was applied to the X and Y-axes.

Seventeen participants undertook the one hour prescribed protocol (10 women; 26 ± 3 years): 1) self-paced walking (5 minutes); 2) brisk walking (5 minutes); 3) ascending and descending eight sets of stairs; 4) 5 minutes of active working tasks (moving around the office reading a document, going down stairs to the photocopier and delivering a message to a colleague); 5) sitting down

### Table 1

<table>
<thead>
<tr>
<th>Protocol 1: Prescribed protocol (n = 17)</th>
<th>Mean criterion devices</th>
<th>Mean W@W-App</th>
<th>Mean difference (95%CI)</th>
<th>MAE</th>
<th>ICC (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking at self-pace; steps (5 min)</td>
<td>523 ± 33.3</td>
<td>539 ± 21.1</td>
<td>-16.8 (-28.9 to -4.6)</td>
<td>17.9</td>
<td>0.85 (0.51 to 0.95)</td>
</tr>
<tr>
<td>Walking faster; steps (5 min)</td>
<td>539 ± 12.4</td>
<td>616 ± 69.7</td>
<td>-21.5  (-69.2 to 26.2)</td>
<td>51.5</td>
<td>0.20 (-2.20 to 0.80)</td>
</tr>
<tr>
<td>Going up stairs; steps (4 floors)</td>
<td>94 ± 6.4</td>
<td>68 ± 31.9</td>
<td>26.1 (10.0 to 42.3)</td>
<td>27.4</td>
<td>0.13 (-1.40 to 0.69)</td>
</tr>
<tr>
<td>Going down stairs; steps (4 floors)</td>
<td>100 ± 5.3</td>
<td>44 ± 13.4</td>
<td>56.0 (39.3 to 72.7)</td>
<td>57.1</td>
<td>-</td>
</tr>
<tr>
<td>Active working tasks; steps (5 min)</td>
<td>471 ± 61.0</td>
<td>438 ± 55.7</td>
<td>33.1 (9.1 to 17.0)</td>
<td>37.5</td>
<td>0.80 (0.47 to 0.93)</td>
</tr>
<tr>
<td>Sitting; seconds (5 min)</td>
<td>300 ± 0.0</td>
<td>302 ± 2.0</td>
<td>1.5 (2.5 to 0.4)</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>Stand up and down 14 times while sitting; seconds sitting (10 min)</td>
<td>583 ± 8.4</td>
<td>570 ± 5.7</td>
<td>13.2 (22.2 to 10.4)</td>
<td>0.67 (0.03 to 0.89)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Protocol 2: Free living protocol (n = 7)</th>
<th>Mean criterion devices</th>
<th>Mean W@W-App</th>
<th>Mean difference (95%CI)</th>
<th>MAE</th>
<th>ICC (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking (steps)</td>
<td>538 ± 195.2</td>
<td>520 ± 250.4</td>
<td>18.4 (-94.2 to 131.0)</td>
<td>-</td>
<td>0.92 (0.54 to 0.97)</td>
</tr>
<tr>
<td>Sitting (min)</td>
<td>96.1 ± 11.8</td>
<td>95.6 ± 12.6</td>
<td>0.5 (-1.3 to 2.2)</td>
<td>-</td>
<td>0.99 (0.97 to 0.99)</td>
</tr>
</tbody>
</table>

95%CI: 95% confidence interval; ICC: intra-class correlation; MAE: mean absolute error.
(5 minutes); and 6) standing up and down from the chair (14 times).
One month later participants were invited to participate in two
hours of continuous monitoring of a normal working day, and seven
women completed the free-living protocol. For criterion measures
during the prescribed and free-living protocol, participants used an
inclinometer ActivPAL3TM on the left hip to detect sitting events
lasting more than three seconds, and a SW200 Yamax Digi-Walker
pedometer placed on the left hip to measure step counts.
Validity of the W@W-App was analyzed by measuring
agreement, intra-class correlation coefficients (ICC) and mean dif-
fferences of sitting time against the inclinometer ActivPAL3TM,
while step counts against the SW200 Yamax Digi-Walker pedom-
eter. The absolute mean error (MAE) was calculated for the
laboratory protocol.

Results

Table 1 shows mean (SD) data for the W@W-App and criterion
measures (ActivPAL3TM and SW200 Yamax Digi-Walker), as well
as their mean differences and ICCs.

During the prescribed protocol, the smallest mean difference
between devices in sitting time was identified when partici-
pants spent 5 minutes sitting without transitions (1.5 seconds;
MAE = 1.5). In contrast, the largest mean difference was found for
sitting with transitions (6.3 seconds; MAE = 13.2). For stepping,
the largest differences between the W@W-App and the pedometer
were found for descending stairs and brisk walking (56 and 21
steps; MAE = 57.1 and 51.5, respectively). The smallest differences
were found for self-paced walking and active working tasks (16
and 13 steps; MAE = 17.9 and 37.5, respectively), with good agree-
ment between the W@W-App and the pedometer (ICC = 0.85 and
0.80, respectively). During free-living conditions, the mean dif-
fERENCE between the W@W-App, the pedometer and the ActivPAL3TM
was 18 steps and 30 seconds of sitting respectively. For both sitting
and self-paced walking, the W@W-App showed excellent levels of
agreement (ICC = 0.99 and 0.92, respectively) compared with crite-
riion measures.

Discussion

This study evaluated the validity of the W@W-App for measur-
ing sitting time and stepping at work. Given the growing evidence
on the risks associated with excessive sitting, having a low-cost
self-monitoring tool that accurately measures occupational sitting
and activity patterns in real time is important for maximizing effec-
tiveness in workplace interventions. The W@W-App demonstrated
accurate measures for desk-based sitting time, especially in pro-
longed periods of sitting, and while moving around performing
work tasks.

Existing laboratory-based and free-living validation studies to
measure sedentary patterns using Apps have found similar results;
with the highest accuracy shown for sitting time and for ambulatory
activities, but not for MVPA.11,12 However, smartphones were pro-
vided by the researchers to control measurement reliability.11,12
In contrast, the W@W-App was installed onto participants’ own
smartphones to assess validity in a real-world, ecological setting.

Furthermore, sedentary patterns in previous studies were
mostly assessed by using accelerometer sensors positioned at the
wrist or waist,7 or by use of different in-built smartphone sensors
supplemented by an online learning activity classification method
to allow normal use of the smartphone.13 Several usability prob-
lems were identified from these processes such as perceived high
cost of the wearables and low accuracy of data measurements9,10
due to the different location of smartphone devices at work, where
employees kept devices in handbags or on the desk. For this
reason, the W@W-App pouch allowed participants to use their own
smartphones (e.g. texting, calling or internet searching) while also
monitoring sedentary patterns during working hours. Although
employees perceived that using the pouch at work was a feasible
option, further investigation needs to explore the usability of the
W@W-App pouch in “occupational sitting reduction” interventions.

The main limitations of this study are the small sample size and
that the W@W-App only operates with the Android smartphone
platform. The majority of participants were women, what is a com-
mmon fact on health promotion interventions when participants are
recruited voluntary.13 Ongoing studies should incorporate a wider
array of new phones and models to compare levels of agreement in
larger and longer studies in free-living conditions.

Despite these limiting factors, this is one of the few studies eval-
uating the validity of an App for measuring sedentary patterns using
participants’ own smartphones sensors under real-life conditions.
The current study provides occupational health practitioners with
a low-cost tool (W@W-App) to accurately monitor prolonged sit-
ting and self-paced walking during working hours in office-based
workers; amplifying the impact workplace health promotion inter-
ventions might have on reducing occupational sitting.

Editor in charge

Cristina Linares Gil.

Transparency declaration

The corresponding author on behalf of the other authors guaran-
tee the accuracy, transparency and honesty of the data and
information contained in the study, that no relevant information
has been omitted and that all discrepancies between authors have
been adequately resolved and described.

What is known about the topic?

Sitting for long periods without interruptions has been
associated with many chronic diseases. Thus, reducing seden-
tary behaviour in desk-based jobs has become a behavioural
risk to be addressed within workplace health promotion pro-
grams. Smartphone sensors have the potential to identify
sedentary patterns and influence behaviour change. However,
measurement accuracy remains unclear.

What does this study add to the literature?

The current study provides occupational health practition-
ers with a valid low-cost tool (W@W-App) that monitors
activity and sedentary patterns in real time in office-based
workers. This is a key issue to effectively modify occupational
sitting time in employees whose work time is dominated by
sedentary tasks.

Authorship contributions

J. Bort-Roig, A. Puig-Ribera and R.S. Contreras conceived the study,
and J. McKenna and N.D. Gilson oversaw its conduct. All
authors participated in the design of the study. J. Bort-Roig and
E. Chirveches-Pérez led data collection with support from A.
Puig-Ribera. J. Bort-Roig and J.C. Martori analysed de data and
interpreted the results. J. Bort-Roig drafted the manuscript, and all
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Conflicts of interest

None.

References