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Measurement of physical activity levels in the Intensive Care Unit and functional outcomes: An observational study

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ABSTRACT

Purpose: Primary aims were: (1) objectively quantify levels of physical activity with the sensewear armband mini-fly motion sensor (SWA-MF), (2) evaluate the correlation of SWA-MF measurement of active and resting energy expenditure against the ICU Mobility scale (IMS) and indirect calorimetry respectively.
Materials and methods: Adults mechanically ventilated ≥48 h and anticipated to remain in ICU ≥ 5 days were included. Physical activity (PA) was measured using a SWA-MF (over the first five days); energy expenditure was measured with both the SWA-MF and the Deltatrac II metabolic cart on day three; highest level of mobility was assessed on the IMS.
Results: Fifty-five participants performed median [IQR] 16.8 [0.6–152.4] minutes of PA per day (defined as >1.0 metabolic equivalent). A strong correlation between active energy expenditure and highest level of mobility (IMS), $r = 0.76$, $p = 0.00$ was observed on day 5. The SWA-MF demonstrated moderate to good agreement with the Deltatrac II metabolic cart ($n = 20$), intra-class correlation co-efficient = 0.71 ($p = 0.00$) for the measurement of energy expenditure on day 3.
Conclusions: Participants demonstrated low levels of PA. Motion sensors may be a promising non-invasive measure of energy expenditure and further investigation is warranted.

1. Introduction

An intensive care unit (ICU) admission is often associated with the development of intensive care unit-acquired weakness (ICU-AW) that results in lower health related quality of life (HRQoL) [1] and poorer functional status [2,3]. However muscle weakness alone does not account for the impairments in physical function and HRQoL that exist years after ICU discharge [4]. Physical activity (PA) is a potentially modifiable risk factor in the development and treatment of ICU-AW and impaired physical function [5]. PA is defined as; any bodily movement produced by skeletal muscles that requires energy expenditure [6]. Whereas exercise is a subcategory of PA and is defined as PA that is 'planned, structured, repetitive, and purposive in the sense that improvement or maintenance of one or more components of physical fitness is an objective' [7]. Recent evidence demonstrates that early rehabilitation/mobilisation is safe and feasible in the ICU setting [8-10]. Despite a growing body of evidence for the safety [11,12] and benefits [13-15] of early rehabilitation in the ICU, recent point prevalence and observational studies demonstrate that current patient activity levels are low [16-19]. Whilst low levels of PA are anticipated early in the ICU stay, it is useful to be able to quantify PA across the ICU stay to measure treatment outcomes.

There has been limited work to date utilising motion sensors in patients during or following an ICU stay. One study reported that objective measures of PA (steps) using motion sensors explained a moderate amount of the variation in HRQoL scores (Short form-36 physical function component) in ICU survivors post hospital discharge ($r^2 = 0.56$, $p < 0.01$) [20]. Previous studies also used motion sensors to measure PA levels in ICU survivors post-hospital discharge [21,22]. Observational data measuring the type, duration and frequency of mobilisation demonstrates low levels of mobilisation in the ICU [23,24] with a number

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of barriers, including: sedation, presence of an endotracheal tube and cardiovascular instability [23,24]. No studies to date have reported using motion sensors within the ICU. This study addresses this gap; therefore the primary aims of this study were to: (1) objectively quantify levels of PA with the sensewear armband mini-fly (SWA-MF) motion sensor, (2) evaluate the correlation of SWA-MF measurement of active and resting energy expenditure against the ICU Mobility scale (IMS) and indirect calorimetry (in a subset of participants) respectively. Secondary aims were to (1) describe the feasibility of using the SWA-MF in the ICU setting and (2) describe the changes in physical outcomes (strength, and physical function) over the ICU stay, mobility levels and the relationship between PA duration (minutes) and physical function.

2. Materials and methods

2.1. Study design and setting

This was a single centre prospective non-interventional observational study conducted in a mixed medical, surgical and trauma quaternary ICU in Melbourne, Australia. A total of sixty consecutive patients were recruited from August 2012 to February 2014. Participants were followed up until acute hospital discharge (censored at day 60). This study is reported in accordance with the STrengthening the Reporting of OBservational Studies in Epidemiology (STROBE) guidelines [25].

2.2. Participants

Participants were included if they were adults 18 years of age or older; mechanically ventilated within 48 h of admission, remained ventilated for at least 48 h and predicted by the ICU physician to remain in the ICU for at least 5 days. Reasons for exclusion included, patients who were unable to mobilise due to major trauma necessitating a specific period of immobilisation (including lower limb fractures); new neurological insult such as stroke, traumatic brain injury or spinal cord injury and poor premorbid mobility (defined as inability to walk independently with or without a gait aid). Patients who were non-English speaking, not Australian citizens (consistent with hospital funding rules, due to ineligibility for Medicare) and being re-admitted to ICU were also excluded from the study. Ethical approval was obtained from the Melbourne Health Human Research Ethics Committee in May 2012 (MH project number: 2012.060). Written informed consent was initially obtained from the next of kin and continuation of consent was sought from the participant once awake and able.

2.3. Procedure

Fig. 1 outlines the procedure. Time points of assessment and measurement tools for each outcome are described below. All patients received a blanket referral for physiotherapy assessment and treatment (respiratory and/or rehabilitation). There were 2.4 full time physiotherapists working within the 24 bed ICU. Rehabilitation commenced once the patient was awake and able to participate in therapy and included (but was not limited to) functional tasks such as: sitting on the edge of the bed, transferring out of bed and mobilising, as well as exercise prescription and use of the tilt table. This unit does not use electrical muscle stimulation or cycle ergometry in physiotherapy care. A maximum of two rehabilitation sessions per day were provided. Participants received all other Medical, Nursing and Allied Health input required as part of their normal care in the ICU. Turning practices in this unit, at the time of this study were up to five times per day. Passive range of motion exercises are not routinely performed as part of standard nursing or rehabilitation practice.

2.4. Outcome measures

2.4.1. Quantification of physical activity with sensewear armband mini-fly motion sensor

The World Health Organisation definition of physical activity is 'any bodily movement produced by skeletal muscles that requires energy expenditure' [6]. Activity levels can be categorised as multiples of resting energy expenditure, for example an activity like walking is 3 metabolic equivalents (METS) because it requires energy expenditure 3 times that required at rest [26,27]. Patients in the ICU setting were expected to have low activity levels, to ensure we captured data at the lower end of the spectrum we used a cut off level of 1 MET for PA. We chose this cut-off to identify time spent above resting metabolic rate [26] and because we anticipated participants to be less active in the ICU. This is the first study of its kind to examine MET levels in the ICU setting therefore there is no prior work which could be used to inform the selection of cut off values.

The SWA-MF armband motion sensor device (BodyMedia Inc., Pittsburgh, Pennsylvania) is a tri-axial accelerometer, which can detect acceleration of body movements in up to three planes. It also includes three physiological sensors, which are: heat flux, skin temperature and galvanic skin response, which enable determination of heat loss, environmental surrounding temperature and humidity [28]. The SWA-MF has been shown to be a reasonably valid tool in the evaluation of energy expenditure in healthy individuals and other patient populations, though over and under-estimation of energy expenditure in these studies are reported [29,30]. Tri-axial accelerometers such as the SWA-MF have been shown to have higher correlation with indirect calorimetry compared to other accelerometers which may be due to the combined physiological sensor and tri-axial plane evaluation [29-32].

The SWA-MF provides data output in one minute epochs for all participants. The 1 MET cut-off was programmed into the sensewear professional software to delineate PA from rest. The SWA-MF was utilised to capture the following data: duration of PA (defined as cumulative time spent at >1 MET), number of steps, total energy expenditure (kcal) and active energy expenditure (kcal). To determine the feasibility of using the SWA-MF in the ICU the following data was obtained from the device: number of days the device was worn, the hours of wear per day and time the device remained in contact with the body. The physiotherapist checked the motion sensors daily to monitor skin integrity and ensure correct placement was maintained [33,34].

Prior to study commencement, participants' gender, age, height and weight were programmed into the sensor. Motion sensors were placed on the posterior aspect of the mid upper arm. The aim was for the device to remain in situ 24 h a day for five days including during physiotherapy treatment sessions. Physical activity duration (cumulative time spent at >1 MET), steps and energy expenditure is reported for individual days.

On the day of application and removal of the SWA-MF participants were unable to wear the device for the full 24 h. Therefore we required participants to have a minimum of 8 h of data per day on three consecutive days to be included in data analysis in line with recommended guidelines for objective PA reporting [33]. Demeyer and colleagues recommend at least three weekdays to obtain a sufficient ICC for activity level [33]. Data was uploaded using the Sensewear Professional Software version 7.0 which provides excel and graphical output on data collected before being exported to IBM SPSS Statistics premium Version 22.0 (Chicago, Illinois) for analysis.

2.4.2. Measurement of energy expenditure

Indirect calorimetry is considered to be the gold standard for determining energy requirements in the ICU setting [35,36] and was used in all participants who remained mechanically ventilated at Day 3 who did not have exclusion criteria precluding the use of indirect calorimetry equipment. Exclusion criteria included: presence of an intercostal catheter with an air leak, if patients required a fraction of inspired oxygen >0.6, extracorporeal membrane oxygenation or infective isolation.