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Novel in situ weighing device for immobile patients

Dear Editor,

Accurate, regular weighing of patients is an important aspect of good clinical practice for both diagnostic and therapeutic purposes.[1] However, nurses face major physical challenges when taking regular weight measurements for immobile patients.[2,3] As our society ages rapidly, the proportion of disabled inpatients will only increase.[4] Despite the availability of several commercial weighing devices, immobile patients are infrequently weighed, as these devices are either expensive, highly customised or impractical to use on a daily basis.

Hence, there exists a need for an accurate, low-cost weighing equipment that can be installed conveniently onto existing hospital beds to minimise patient transfer. This paper reports our project's development of a novel weighing device with these features, and its comparative performance against 3 commercial weighing devices in terms of accuracy, ease of use and cost. This project was a joint effort in Singapore, involving Tan Tock Seng Hospital's Department of Geriatric Medicine and the National University of Singapore's Department of Electrical and Computer Engineering.

Design and evaluation. Our novel in situ under-mattress weighing device consists of modular wireless scales that are retrofittable and scalable for hospital beds with different frame designs or number of bed panels (Fig. 1). Each module is fastened onto the bed frame with Velcro straps prior to the patient's admission, and no further installation is required after the first installation. While the patient is lying on the bed, the total weight of the patient (tabulated from each module) is read off a wireless central display device. The wireless modules allow for easy installation, transportation and disinfection. The device comes with a wall plug charger that recharges the 4 modules at once. The study was approved by the National Healthcare Group Domain Specific Review Board.

After its development, a study was conducted where the novel device's accuracy and ease of use were compared against 3 competitors' devices: scale-integrated bed (CareAssist ES155, Hillrom, Chicago, US), under-bed scale (Charder MS6000, Charder Medical, Taichung City, Taiwan) and sitting scale (SECA 952, Seca GmbH & Co. KG, Hamburg, Germany).

Two accuracy measures comprising absolute accuracy and incremental accuracy, were used to evaluate the accuracy of the devices. These measures are as specified by international standards for weighing devices.[5] Each experiment with known weights was repeated 5 times on each device, and overall mean and 2 standard deviations were computed. Finally, the device's degree of similarity in absolute accuracy was assessed using the intraclass correlation coefficient (ICC) as per Koo and Li.[6]

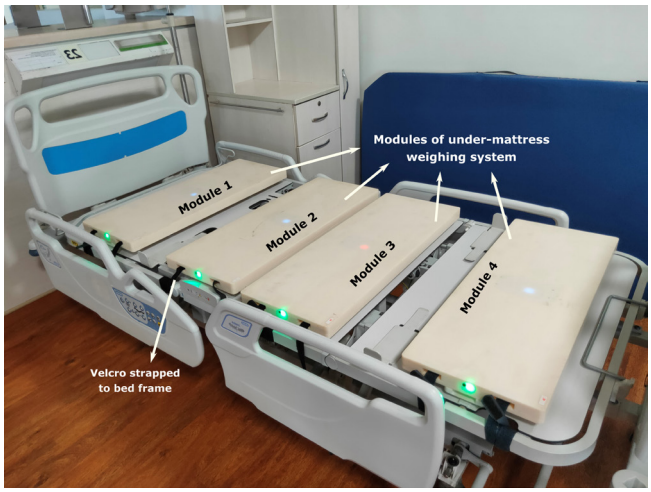

Fig. 1. Top view of the in situ under-mattress weighing device, with mattress removed. The modular devices (modules 1–4) are placed on top of 4 panels of the hospital bed frame. Velcro straps fasten the devices to the side of the bed frame. For a 4-panel hospital bed, 4 modules make up the weighing device.

As nurses are the end-users of the weighing devices, volunteer nurses' ratings were used to measure the devices' ease of use. Based on a significance level of 0.05 and 90% power to detect a mean difference of 1 in the rating, 150 participants were recruited.

The nurses were instructed on the installation and usage of the devices. Pairs of participants took turns to record each other's weight on each device. After their weighing experience with each device, they were asked to assess the 4 devices' ease of use based on a hypothetical scenario where they had to weigh an immobile patient daily for a week. The ease of use ratings were presented as a 5-point Likert scale, from "(1) Very easy" to "(5) Very difficult". The median score of the ease of use ratings was used for comparison of the devices.

Outcome of evaluation. All devices had an absolute accuracy and incremental accuracy that met the

requirements of the UK Weighing Federation for medical devices[7] (Table 1). The repeatability of measurements was also acceptable per requirements. There was also excellent agreement in the absolute accuracy of all devices by the ICC measure.

The nurses ranked all the 4 devices' ease of use, from the easiest to most difficult to use, with median scores of 1, 2, 3 and 4, respectively (Table 1).

Discussion. The novel device prototype developed in this study fared well against 3 competitors' devices in both technical and practical aspects. Given their similarity in accuracy, the devices were further compared for their ease of use and cost (Table 1).

Factors affecting the devices' ease of use include time taken to install the device, weight of the device and physical strain induced during weighing. Thus, sitting scales, which require immobile patients to be transferred to them, were ranked as difficult in our study. Hoists, including those with weighing functionalities, require effortful strapping of immobile patients. While direct patient transfer is avoided with the under-bed scale, it is physically straining for nurses to bend down to position heavy scales and roll the bed with a patient onto them. Ease of use has important implications in determining whether the device is ultimately used in the wards for regular weight measurements of immobile patients.

While scale-integrated beds offer the greatest convenience for nurses, not all hospitals may find them cost-effective. We acknowledge that the cost data in Table 1 is not directly comparable, since the cost for the novel device reflects its assembly cost price, while the cost of other devices consisted cost to purchase them for our study.

Though the novel device was ranked second for ease of use, its price would be much lower than that of the scale-integrated bed even at its reduced bulk purchase price. Should the novel device become a commercial product and its market price exceed the cost price reported, we are confident that it will present as a good economical and practical alternative to the other devices in our study, given its scalable modular design.[8]

Apart from the device's ease of use and cost, other practical considerations include size, storage space requirements and design issues. Scale-integrated beds do not require storage as they are used in the wards. Sitting and under-bed scales take up minimal space while weighing hoists require larger storage space. Our device can be attached to an existing ward bed, or disassembled and stored as a portable device, thus taking up a similar storage space as sitting and under-bed scales.

In the face of economic constraints where only a proportion of ward beds may include a weighing function, the novel device's design converts any ordinary ward bed to a weighing bed for the duration of a clinical need. This reduces additional disinfection work when patients require weighing, given that only disinfection of the novel device is required. In contrast, the use of scale-integrated beds, which involves transferring patients from an ordinary bed to the scale-integrated bed, would require disinfection of 2 beds.

There is scope to improve our study prototype by adding features such as fall detection and vitals monitoring in a cost-efficient manner.

Having a device in the wards to assist nurses with weighing immobile patients will not only improve the productivity of nurses but also increase the quality of patient care, especially in the geriatric wards and nursing homes. This study validated the novel device as a good cost-effective alternative to commercial devices in terms of accuracy and ease of use.

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Table 1. Comparison of the 4 devices' accuracy, rating for ease of use and actual cost

Device	Absolute error (kg)[a,b]	Incremental error (kg)[a,b]	Ease of use[c]	Cost (SGD)
Under-mattress scale (novel device)	0.2±0.0	0.0±0.0	2 (Easy)	1,500[d]
Scale-integrated bed	0.2±0.1	0.1±0.0	1 (Very easy)	9,800
Under-bed scale	0.1±0.1	0.0±0.0	3 (Average)	3,600
Sitting scale	0.2±0.1	0.0±0.0	4 (Difficult)	1,600

[a] Data represented as mean root mean square error ± 2 standard deviations
[b] Acceptable absolute and incremental errors are to be <0.2kg[7]
[c] Data represented as the median score of the ease of use ratings
[d] Cost for the novel device reflects its assembly cost price

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REFERENCES

1. Evans L, Best C. Accurate assessment of patient weight. Nurs Times 2014;110:12-4.
2. Davis KG, Kotowski SE. Prevalence of Musculoskeletal Disorders for Nurses in Hospitals, Long-Term Care Facilities, and Home Health Care: A Comprehensive Review. Hum Factors 2015; 57:754-92.
3. Pompeii LA, Lipscomb HJ, Schoenfisch AL, et al. Musculoskeletal injuries resulting from patient handling tasks among hospital workers. Am J Ind Med 2009;52:571-8.
4. Gu D, Gomez-Redondo R, Dupre ME. Studying disability trends in aging populations. J Cross Cult Gerontol 2015;30:21-49.
5. National Institute of Standards and Technology (NIST). Specifications, tolerances and other technical requirements for weighing and measuring devices (NIST Handbook 44, 2020 Edition). Available at: https://www.nist.gov/system/files/documents/2021/05/05/00-20-hb44-web-final_0.pdf. Accessed on 3 June 2021.
6. Koo TK, Li MY. A guideline of selecting and reporting Intraclass Correlation Coefficients for reliability research. J Chiropr Med 2016;15:155-63.
7. UK Weighing Federation. Guidance notes relating to the legal prescription of medical weighing scales, June 2002. Available at: http://www.ukwf.org.uk/c2/uploads/medicalguidancenotes.pdf. Accessed on 3 June 2021.
8. Boothroyd G, Dewhurst P, Knight WA. Product Design for Manufacture and Assembly. 2nd Edition. New York: CRC Press; 2002.

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