ORIGINAL RESEARCH

The Relationship Between Physical Activity and Limited Range of Motion in the Older Bedridden Patients

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ABSTRACT

Background

The purpose of this study is to examine the association between physical activity and contracture in older patients confined to bed in long-term care (LTC) facilities.

Methods

Patients wore ActiGraph GT3X+ for 8 hours on their wrists, and vector magnitude (VM) counts were obtained as the amount of activity. The passive range of motion (ROM) of joints was measured. The severity of ROM restriction classified, as the tertile value of the reference ROM of each joint, was scored 1–3 points. Spearman's rank correlation coefficients (Rs) were used to measure the association between the VM counts per day and ROM restrictions.

Results

The sample comprised 128 patients with a mean (SD) age of 84.8 (8.8) years. The mean (SD) of VM was 84574.6 (115195.2) per day. ROM restriction was observed in most joints and movement directions. ROMs in all joints and movement directions, except wrist flexion and hip abduction, were significantly correlated with VM. Furthermore, the VM and ROM severity scores showed a significant negative correlation (Rs = -0.582, $p < .0001$).

Conclusions

A significant correlation between the physical activity and ROM restrictions indicates that a decrease in the amount of physical activity could be one of the causes of contracture.

Key words: long-term care, older people, physical activity, restriction of range of motion

INTRODUCTION

Older patients who are confined to bed in long-term care (LTC) facilities such as nursing homes have difficulty moving voluntarily. These patients are among the most vulnerable populations and often have medical histories of neurological disorders. Furthermore, they often cannot move their extremities or roll themselves over in bed, and are dependent on their caregivers for basic activities of daily living (ADL) such as bathing, feeding, moving about in bed, and getting into chairs.(1) This problem may be compounded by the presence of joint contractures.(2) Therefore, contracture limits self-reliance, reduces physical activity, and significantly decreases quality of life and increases staffing demands. Patients in LTC facilities often experience contractures in almost all joints.

Joint contracture is a limitation in the passive range of motion (ROM) of a joint, and it is understood to be an alteration in the viscoelastic properties of periarticular connective tissue, including muscles. The risk factors for joint contractures are not well understood;(2) however, immobility or inactivity seems to be the most important factor.(4) In fact, patients in LTC facilities have severe joint contractures due to the immobilization associated with prolonged bed rest.(3,5-9) However, there are no reports examining the relationship between contracture and the amount of physical activity.

With recent advancements in movement sensor technologies, wearable sensors such as accelerometers have become available in physical activity research, often used to measure movements associated with daily living, objectively and directly.(10) These devices provide a more accurate investigation of physical activity through the whole intensity spectra, including light intensity or sedentary activity. Thus, it is considered that physical activity in older patients in LTC facilities can be evaluated using these devices.(11) Particularly, the ActiGraph has been used often in studies with older adults.

This device was noted to be highly correlated with observed number of steps when worn by residents in long-term care facilities.(12) Furthermore, Resnick and Galik showed that the number of counts of activity measured with the ActiGraph are associated with the observational measurement in older patients in LTC facilities.(13) However, there are no studies which examine the association between physical activity and progression of joint contracture in these patients.

In this study, we investigate physical activity assessed using accelerometers, and joint contracture in the neck and upper and lower limbs in patients confined to bed in LTC facilities. Our specific aim is to examine the association between physical activity and progression of joint contracture in these patients. We hypothesize that this investigation will further highlight the importance of physical activity in preventing the progression of joint contracture.

METHODS

The study protocol was approved by the Research Ethical Committee of the Graduate School of Biomedical Sciences at Nagasaki University (approval number: 19091202).

Patients

We analyzed the clinical data of consecutive LTC residents who were under care at the Nagasaki Memorial Hospital from July 2017 to July 2019. To be included, the patients' frailty status was assessed by the Canadian Study of Health and Aging (CSHA)-Clinical Frailty Scale.(14) This tool is used based on the judgment of clinicians, and has been validated in a population-based study of Canadian seniors. It classifies older adults as very fit (level 1), well (level 2), well with treated comorbidities (level 3), apparently vulnerable (level 4), mildly frail (level 5), moderately frail (level 6), severely frail (level 7), very severely frail (level 8), or terminally ill (level 9). Informed consent was obtained from all the patients prior to commencement of the study. At instances where it was difficult for the patient to understand the explanation and purpose of the study, an informed assent was obtained. Before study entry, demographic characteristics of participants such as age, sex, disease status, clinical frailty scale, nutrition management, and length of hospitalization were collected.

Measurement of Physical Activity

Physical activity was measured using a wrist-worn triaxial accelerometer (ActiGraph GT3X+; ActiGraph Corp., Pensacola, FL) attached to the non-dominant wrist. The ActiGraph GT3X+ is a small (38 × 37 × 18 mm), lightweight, and water-resistant accelerometer that has a dynamic range of ± 6 gravitational units, and stores data locally.(15) The device was set to record the triaxial accelerations at 30 Hz. Patients were asked to wear the accelerometer device for 8 hr (9:00–17:00) a day. They were instructed that they did not need to remove the devices when showering or bathing.

ActiGraph accelerometer data were extracted using ActiLife software version 6 (ActiGraph Corp, Pensacola, FL, USA) in 60-second epochs. Accelerations were combined across axes into a single vector magnitude (VM) value using the equation $\sqrt{(x^2 + y^2 + z^2)}$.(15) Although step counts were derived from the built-in algorithm of the ActiLife software,(16) VM is considered more suitable as an index of activity rather than the number of step counts because all participants of this study found it difficult to walk independently and most all participants found it difficult to walk even with help. In addition, raw ActiGraph acceleration signals can be processed using one of two filters: a normal filter or a low-frequency extension filter. According to ActiGraph, the low-frequency extension filter permits detection of lower intensity movements, and thus may be useful for slow-moving populations such as the elderly.(17) In this study, we chose the low-frequency filter. We extracted the number of VMs per day, and calculated the mean and standard deviation (SD).

Measurement of Range of Motion

The physiotherapists (C.M., S.N., H.A., and K.N.) evaluated the passive ROM of the patients' joints using a goniometer. The ROM we measured were: cervical spine (neck); flexion, extension, rotation, and lateral bending, shoulder; flexion and abduction, elbow; flexion and extension, wrist; flexion and extension, hip; flexion and abduction, knee; flexion and extension, and ankle; flexion.(18,19)

Severity of Range of Motion Restriction

We classified the severity of ROM restriction into mild, moderate, and severe according to the tertile value of the reference ROM for each movement direction in each joint. In addition, we scored the severity of each ROM restriction as follows: the first (worst) tertile was 3 points, the second (intermediate) was 2 points, and the third (best) was 1 point. Then, the severity of the ROM restriction in the whole body was judged based on the total points (from 28 to 85 points). The tertiles of ROM for each movement direction of each joint were as follows:

Neck spines: flexion (worst tertile < 15°, intermediate tertile 20–35°, best tertile 40–60°), extension (worst tertile <15°, intermediate tertile 20–30°, best tertile 35–50°), rotation (worst tertile < 15°, intermediate tertile 20–35°, best tertile 40–60°), and lateral bending (worst tertile < 15°, intermediate tertile 20–35°, best tertile 40–60°).

Shoulder: flexion (worst tertile <55°, intermediate tertile -60-115°, best tertile -120–180°), and abduction (worst tertile < 55°, intermediate tertile 60–115°, best tertile 120–180°).

Elbow: flexion (worst tertile < 45°, intermediate tertile 50–95°, best tertile 100–145°), and extension (worst tertile < -105°, intermediate tertile -100– -55°, best tertile -50–5°).

Wrist: flexion (worst tertile < 25°, intermediate tertile 30–55°, best tertile 60–90°), and extension (worst tertile < 20°, intermediate tertile 25–45°, best tertile 50–70°).

Hip: flexion (worst tertile < 40°, intermediate tertile 45–80°, best tertile 85–125°), and abduction (worst tertile <10°, intermediate tertile 15–25°, best tertile 30–45°).

Knee: flexion (worst tertile < 40°, intermediate tertile 45–85°, best tertile 90–130°), and extension (worst tertile < -90°, intermediate tertile -85°− -45°, best tertile -40–0°).

Ankle: flexion (worst tertile < 5°, intermediate tertile 10°, best tertile 15–20°).

Sample Size Calculation

There are no studies that examined the relationship between amount of physical activity and ROM. We used G*Power 3 to perform a preliminary test force analysis and to estimate the required sample size. The power was set at 0.8, and the significance level (a) was set at 0.01. Effect size for point biserial model was set at 0.3. The power analysis indicated that 122 patients were required for evaluations with Spearman's rank correlation coefficients.

Data Analysis

We examined the characteristics of participants such as age, sex, BMI, clinical frailty scale, disease status, Charlson Comorbidity Index, nutrition management, and length of hospitalization. The number of participants divided into tertiles was counted.

The average, standard deviation, and median of the ROM angles of each joint, and the movement direction were calculated. Spearman's rank correlation coefficients were used to measure the monotonic association between the VM of wrist-worn accelerometers and ROM angles of each joint and movement direction, as well as the severity score of the ROM of the whole body. Statistical analyses were performed using SPSS for Windows version 22.0 (IBM SPSS Statistics, Armonk, NY). An arbitrary level of 5% statistical significance (two-tailed) was assumed.

RESULTS

We enrolled 128 patients (79 females; 49 males) and Table 1 summarizes the patients' characteristics. Among them, two patients had an amputated thigh, and one had an amputated ankle. The mean (SD) age of the 128 patients in this study was 84.8 (8.8) years. Two patients scored 5, six scored 6, ninety-three scored 7, and twenty-seven scored 8 on the CSHA Clinical Frailty Scale. The mean (SD) and median of length of stay of the participants was 543.6 (927.7) days and 213.5 days, respectively.

Figure 1 shows a histogram of the number of patients separated by every 10,000 VM counts. The histogram shows a distorted distribution on the right. The mean (SD) and median of VM from the accelerometer were 84574.6 (115195.2) and 35014.2/day, respectively.

Table 2 shows the number of patients, mean (SD), and median ROM for all joints and movement directions and each patient divided by tertile. From the results of mean (SD) of ROM, there were restrictions in most joints and movement directions except elbow and knee flexion, which were 134.4° (15.9°) and 129.1° (26.7°), respectively. The number of first tertile (worst) was largest at cervical spine and ankle flexion; that of second tertiles (intermediate) were largest at cervical spine rotation and lateral bending, shoulder flexion and abduction, and hip abduction; and that of third tertiles (best) was largest at cervical spine extension, elbow flexion and extension, wrist flexion and extension, hip flexion, and knee flexion and extension.

Table 3 shows the Spearman's correlations between ROM and wrist accelerometer measures. The results show that ROMs in all joints and movement directions, except wrist flexion and hip abduction, were significantly correlated with VM. The relationship between the amount of activity and contracture was higher in the upper limbs (0.300 < Spearman's rho < 0.562) than in the lower limbs (0.133 < Spearman's rho < 0.350).

Figure 2 shows scatter plots of VM counts and ROM severity score of the whole body. We found that VM counts were significantly negatively correlated with the ROM severity score (Spearman's rho = -0.582, *p* < .0001) (Figure 2).

TABLE 1.
Characteristics of participants

	n/ Mean ± SD (median)
Age (yrs)[a]	84.8 ± 8.8 (86)
Sex[b]	
Men/Women	49/ 79
Body mass index (kg/m^2)[a]	18.9 ± 12.6 (17.5)
Clinical Frailty Scale[b] 5; mildly frail/ 6; moderately frail/ 7; severely frail/ 8; very severely frail	2/ 6/ 93/ 27
Disease[b]	
Cerebrovascular disease	42
Pneumonia	24
Cancer	11
Heart failure	10
Orthopedic disease	6
Respiratory disease	5
Digestive disorders	6
Other	24
Charlson Comorbidity Index[b] 0; Low/ 1-2; Medium/ 3-4; High/ 5; Very High	0/ 32/ 48/ 48
Nutrition Management[b]	
Enteral nutrition oral/tube	50/ 60
Parenteral nutrition	18
Length of hospitalization (days)[a]	543.6 ± 927.7 (213.5)
VM counts from the accelerometer per day[a]	84574.6 ± 115195.2 (35014.2)

[a] Mean ± SD (median) is noted.
[b] Frequency is noted, except where mean ± SD (median) is noted.
VM = vector magnitude

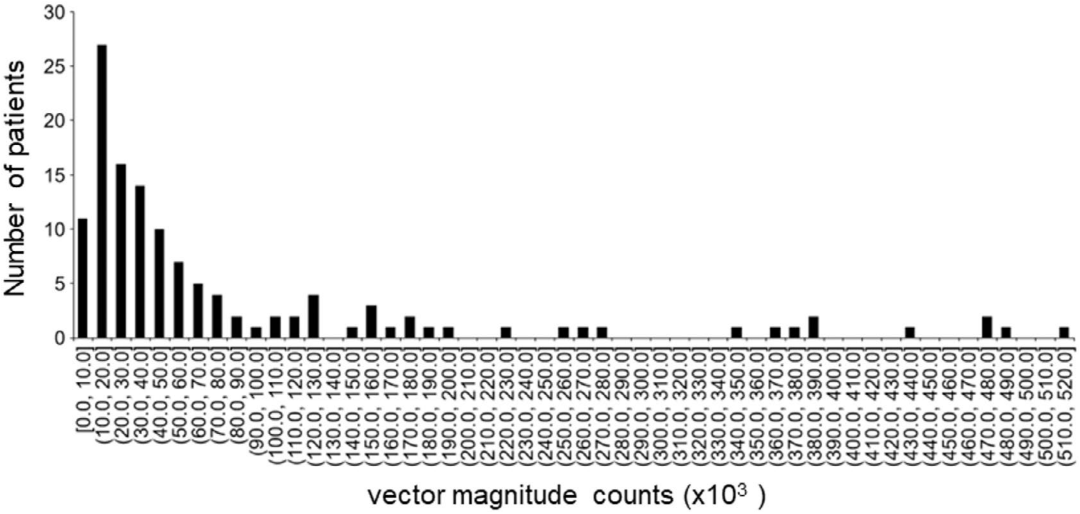

FIGURE 1. Historgrams of vector magnitude counts measured with wrist-worn accelerometer

DISCUSSION

The results of this study show that older patients in LTC are inactive and have ROM restrictions. A significant correlation was found between the amount of physical activity and ROM restrictions of each joint. Furthermore, a significant negative correlation was found between the amount of physical activity and ROM severity score of the whole body. From these results, it is considered that a decrease in physical activity may be one of the causes of contracture. To the best of our knowledge, no previous studies have highlighted the aforementioned points.

Recently, many studies have recognized the importance of promoting physical activity. For example, Wen *et al*. reported that, compared with individuals in the inactive group, those in the low-volume activity group who exercised for an average of 92 min per week or 15 min a day had a 14% reduced risk of all-cause mortality and added life expectancy (3 years).(20) However, few studies have investigated the activity of older patients who are confined to bed in LTC facilities. This study measured and reported the activity of older patients who were confined to bed in LTC facilities. The mean (SD) of VM from the ActiGraph is 2190625 (597108) per day in free-living older women.(16) The mean (SD) of VM from the accelerometer of the participants in our study was 84574.6 (115195.2), which was 0.4% less than that of older women living free reported in a previous study.(16) Thus, it can be seen that the activity of participants in this study was very low.

The results of this study showed that there were significant ROM restrictions in most joints and movement directions. Previous studies have indicated that patients in LTC facilities have joint contractures. The results of two studies by Wagner *et al*., indicated that more than 60% of residents have at least one contracture.(5,6) The most common sites of contracture were the hands and knees.(21) 73.2% of older persons in geriatric settings have joint contractures localized in at least one knee, 61.1% in at least one hand and hip, 53.7% in at least one shoulder, 36.2% in at least one elbow, 39.6% in at least one ankle, and 12.1% in the neck.(3) These studies did not measure passive physiological ROM using goniometers, thus, the severity of ROM restrictions are not clear. We divided ROM restrictions by tertiles, and it is considered that the restriction becomes more severe during neck (cervical spine) and ankle flexion compared to other joints or movement directions. On the other hand, elbow and knee flexion were not severely affected.

We studied the correlations between the ROM and wrist accelerometer measures in this study. To the best of our knowledge, no studies have examined the relationship between activity and ROM in this population. In particular, we found that the relationship between the amount of activity and contracture was higher in the upper limbs than in the lower limbs in our study. The details of this result are unknown, but it may be related to the wearing of ActiGraph on the wrist. In addition, the results of this study showed no significant correlation between the amount of activity and the ROM in wrist flexion and hip abduction. This suggests that restriction of ROM in wrist flexion and hip abduction is due to problems other than physical activity in older patients who are confined to bed in LTC.

This study showed that the lower the amount of activity, the higher the severity score. Therefore, we infer that the lower the amount of physical activity, the more severe the ROM restriction throughout the body. In fact, patients in this study corresponded to 5-8 on the clinical frailty scale; thus, they are limited in basic ADL and require routine assistance. Patients in this study were considered less active because they had difficulty moving on their own. Recently, Lam *et al*. reported impaired mobility was the leading independent risk factors for the development of new joint contractures.(22) Furthermore, other previous studies have demonstrated that the lower the ADL capacity and functional status, the greater the occurrence and severity of contractures,(5,23,24) and although these studies did not directly measure the amount of activity in the elderly, it is thought that a decrease in activities

TABLE 2.
Number and percentage of joints divided by tertile of reference range of motion of each joints and movement directions

	Total	*First (worst)*	*Second (intermediate)*	*Third (best)*
Cervical spines flexion				
Number of joint (n/ %)[a]	128/ 100	53/ 41.4	37/ 28.9	38/ 29.7
Range of motion (mean ± SD/ median)[b]	24.9 ± 17.5/22.5	7.7 ± 7.1/10	27.3 ± 6.0/25	46.4 ± 6.3/45
Cervical spines extension				
Number of joint (n/ %)	128/ 100	21/ 16.4	50/ 39.1	57/ 44.5
Range of motion (mean ± SD/median)	30.9 ± 15.4/30	9.3 ± 10.4/15	24.8 ± 4.3/25	44.3 ± 9.5/40
Cervical spines rotation				
Number of joint (n/ %)	256/100	52/20.3	112/43.8	92/35.9
Range of motion (mean ± SD/median)	32.2 ± 16.1/30	11.3 ± 4.7/15	27.2 ± 5.4/25	50.1 ± 8.8/50
Cervical spines lateral bending				
Number of joint (n/ %)	256/100	109/42.6	129/50.4	18/7.0
Range of motion (mean ± SD/median)	19.8 ± 11.2/20	11.6 ± 5.0/15	23.5 ± 4.0/20	38.1 ± 4.2/35
Shoulder flexion				
Number of joint (n/ %)	256/100	21/8.2	165/64.5	70/27.3
Range of motion (mean ± SD/median)	98.3 ± 32.3/95	46.7 ± 8.3/50	86.4 ± 15.0/85	141.9 ± 15.3/142.5
Shoulder abduction				
Number of joint (n/ %)	256/100	30/11.7	165/64.5	61/23.8
Range of motion (mean ± SD/median)	91.4 ± 31.9/85	44.3 ± 8.3/45	83.5 ± 15.8/80	136.1 ± 16.9/130
Elbow flexion				
Number of joint (n/ %)	256/100	1/0.4	8/3.1	246/96.1
Range of motion (mean ± SD/median)	134.4 ± 15.9/140	40/40	86.3 ± 8.8/87.5	136.6 ± 11.3/140
Elbow extension				
Number of joint (n/ %)	256/100	3/1.2	34/13.3	219/85.5
Range of motion (mean ± SD/median)	-23.0 ± 25.4/-15	-115 ± 5.0/-115	-68.2 ± 12.9/-70	-14.7 ± 15.1/-10
Wrist flexion				
Number of joint (n/ %)	256/100	14/5.5	114/44.5	128/50.0
Range of motion (mean ± SD/median)	55.4 ± 18.8/55	7.9 ± 12.4/7.5	45.3 ± 7.3/45	69.7 ± 10.0/65
Wrist extension				
Number of joint (n/ %)	256/100	42/16.4	75/29.3	139/54.3
Range of motion (mean ± SD/median)	45.7 ± 25.0/50	1.2 ± 19.4/10	38.4 ± 6.9/40	62.7 ± 10.2/60
Hip flexion				
Number of joint (n/ %)	256/100	4/1.6	40/15.6	212/82.8
Range of motion (mean ± SD/median)	95.2 ± 17.1/95	30.0 ± 8.2/30	71.9 ± 9.6/75	100.8 ± 11.0/100
Hip abduction				
Number of joint (n/ %)	256/100	68/26.6	121/47.3	67/26.2
Range of motion (mean ± SD/median)	19.8± 10.4/20	6.6 ± 3.9/5	20.0 ± 4.0/20	33.0 ± 3.8/30
Knee flexion				
Number of joint (n/ %)	253/100	6/2.4	12/4.7	235/92.9
Range of motion (mean ± SD/median)	129.1 ± 26.7/135	28.3 ± 9.3/30	73.3 ± 11.7/75	135.1 ± 15.7/140
Knee extension				
Number of joint (n/ %)	253/100	3/1.2	37/14.6	213/84.2
Range of motion (mean ± SD/median)	-21.3 ± 22.0/-15	-105 ± 8.7/-105	-60 ± 12.4/-60	-13.3 ± 10.8/-10
Ankle flexion				
Number of joint (n/ %)	252/100	188/74.6	35/13.9	29/11.5
Range of motion (mean ± SD/median)	-3.1 ± 15.0/0	-8.6 ± 13.3/-5	10.0/10	17.1 ± 3.1/15

[a] All values for number of joint reported as frequency (n) and percentages (%).

[b] All values for range of motion reported as mean ± SD and median.

TABLE 3.
Spearman’s correlations between range of motion and wrist accelerometer measurements

	R_s[a]	*P value*
Neck flexion	0.425	p < .0001
Neck extension	0.297	p = .0006
Neck rotation	0.435	p < .0001
Neck lateral bending	0.215	p = .0005
Shoulder flexion	0.562	p < .0001
Shoulder abduction	0.541	p < .0001
Elbow flexion	0.300	p < .0001
Elbow extension	0.391	p < .0001
Wrist flexion	0.067	p = 2860
Wrist extension	0.462	p < .0001
Hip flexion	0.217	p = .0005
Hip abduction	0.122	p = .0514
Knee flexion	0.133	p = .0342
Knee extension	0.226	p = .0003
Ankle flexion	0.350	p < .0001

[a] Spearman’s Rank Correlation Coefficient (R_S) between the VM of wrist-worn accelerometers and ROM angles of each joint and movement direction.

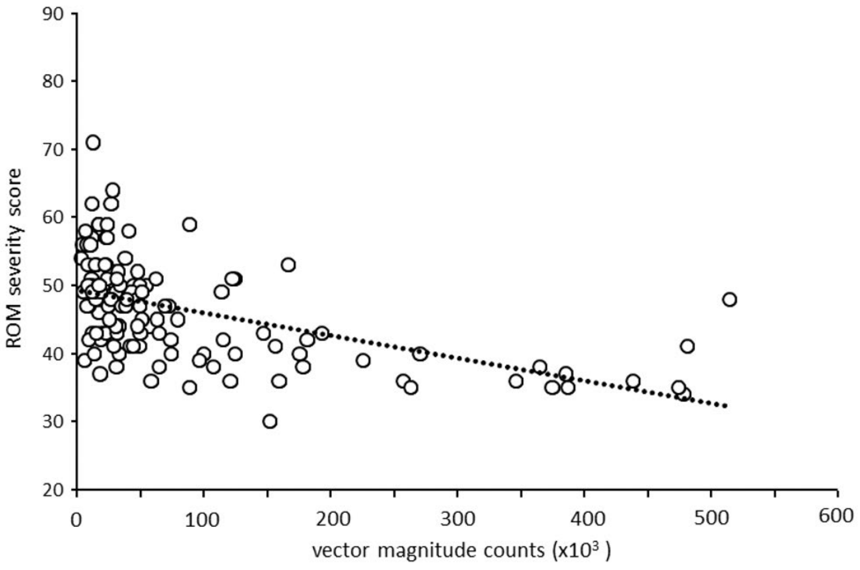

FIGURE 2. Scatter plots of vector magnitude counts and ROM severity score

of daily living leads to a decrease in the overall amount of activity, supporting our results.

This study has several limitations. First, although previous studies measured the amount of activity of participants for seven days or more using ActiGraph,(20,25,26) we measured it for only one day in this study. However, our participants’ daily activity pattern is similar every day because of the limitations of movements and life space, and it is assumed that the amount of activity in one day will be almost the same as the average of the amount in seven days or more. Second, we measured the amount of activity using an ActiGraph on the wrist because of its ease of care during ADL. Normally, it is desirable to measure the amount of activity by wearing an ActiGraph on the waist.(26) Thus, we need to detect the difference in the amount of activity measured by placing the ActiGraph on the wrist or waist in future studies. Third, the method of calculating the severity score used in this study was developed by us, and its reliability and validity have not been examined. However, there are no evaluation methods that reflect the severity of whole-body contractures. Therefore, it is necessary to establish better evaluation methods in future studies.

CONCLUSION

We suggest that physical activity may affect not only the ROM of a single joint, but also contracture of the whole body. Therefore, an increase in physical activity is useful for improving the ROM of bedridden patients in LTC facilities.

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CONFLICT OF INTEREST DISCLOSURES

We have read and understood the *Canadian Geriatrics Journal*'s policy on conflicts of interest disclosure and declare there are no conflicts of interest.

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REFERENCES

1. Fox P, Richardson J, McInnes B, Tait D, Bedard M. Effectiveness of a bed positioning program for treating older adults with knee contractures who are institutionalized. *Phys Ther*. 2000 Apr;80(4):363–72. doi: 10.1093/ptj/80.4.363
2. du Toit M. Prevention of contractures in older people living in long-term care settings. *Nurs Older People*. 2018 May 31;30(4):24–30. doi: 10.7748/nop.2018.e1023
3. Offenbächer M, Sauer S, Rieß J, Müller M, Grill E, Daubner A, *et al*. Contractures with special reference in elderly: definition and risk factors—a systematic review with practical implications. *Disabil Rehabil*. 2014;36(7):529–38. doi: 10.3109/09638288.2013.800596
4. Bartoszek G, Fischer U, Grill E, Müller M, Nadolny S, Meyer G. Impact of joint contracture on older persons in a geriatric setting: a cross-sectional study. *Z Gerontol Geriatr*. 2015 Oct;48(7):625–32. doi: 10.1007/s00391-015-0895-y
5. Wagner LM, Capezuti E, Brush BL, Clevenger C, Boltz M, Renz S. Contractures in frail nursing home residents. *Geriatr Nurs*. 2008 Jul-Aug;29(4):259–66. doi: 10.1016/j.gerinurse.2007.09.002
6. Wagner LM, Clevenger C. Contractures in nursing home residents. *J Am Med Dir Assoc*. 2010 Feb;11(2):94–99. doi: 10.1016/j.jamda.2009.04.010
7. Fischer U, Müller M, Strobl R, Bartoszek G, Meyer G, Grill E. Prevalence of functioning and disability in older patients with joint contractures: a cross-sectional study. *Eur J Phys Rehabil Med*. 2014 Jun;51(3):269–79.
8. Gnass I, Bartoszek G, Thiesemann R, Meyer G. Joint contractures in older age. A systematic literature review. *Z Gerontol Geriatr*. 2010 Jun;43(3):147–57. doi: 10.1007/s00391-009-0089-6.
9. Fergusson D, Hutton B, Drodge A. The epidemiology of major joint contractures: a systematic review of the literature. *Clin Orthop Relat Res*. 2007 Mar;456:22–29. doi: 10.1097/BLO.0b013e3180308456
10. Atkin AJ, Gorely T, Clemes SA, Yates T, Edwardson C, Brage S, *et al*. Methods of measurement in epidemiology: sedentary behaviour. *Int J Epidemiol*. 2012 Oct;41(5):1460–71. doi: 10.1093/ije/dys118
11. Corder K, Brage S, Ekelund U. Accelerometers and pedometers: methodology and clinical application. *Curr Opin Clin Nutr Metab Care*. 2007 Sep;10(5):597–603.
12. Cohen-Mansfield J, Werner P, Culpepper WJ, Wolfson M, Bickel E. Assessment of ambulatory behavior in nursing home residents who pace or wander: a comparison of four commercially available devices. *Dement Geriatr Cogn Disord*. 1997 Nov-Dec;8(6):359–65. doi: 10.1159/000106656
13. Resnick B, Galik E. The reliability and validity of the physical activity survey in long-term care. *J Aging Phys Activ*. 2007 Oct;15(4):439–58. doi: 10.1123/japa.15.4.439
14. Rockwood K, Song X, MacKnight C, Bergman H, Hogan DB, McDowell I, *et al*. A global clinical measure of fitness and frailty in elderly people. *CMAJ*. 2005 Aug 30;173(5):489–95. doi: 10.1503/cmaj.050051
15. Bailey RR, Klaesner JW, Lang CE. Quantifying real-world upper-limb activity in nondisabled adults and adults with chronic stroke. *Neurorehabil Neural Repair*. 2015 Nov-Dec;29(10):969–78. doi: 10.1177/1545968315583720
16. Kamada M, Shiroma EJ, Harris TB, Lee IM. Comparison of physical activity assessed using hip- and wrist-worn accelerometers. *Gait Posture*. 2016 Feb;44:23–28. doi: 10.1016/j.gaitpost.2015.11.005
17. Duncan S, Stewart T, Bo Schneller M, Godbole S, Cain K, Kerr J. Convergent validity of ActiGraph and Actical accelerometers for estimating physical activity in adults. *PLoS One*. 2018 Jun 12;13(6):e0198587. doi: 10.1371/journal.pone.0198587
18. Soucie JM, Wang C, Forsyth A, Funk S, Denny M, Roach KE, *et al*. Range of motion measurements: reference values and a database for comparison studies. *Haemophilia*. 2011 May;17(3):500–07. doi: 10.1111/j.1365-2516.2010.02399.x
19. Whitcroft KL, Massouh L, Amirfeyz R, Bannister G. Comparison of methods of measuring active cervical range of motion. *Spine*. 2010 Sep 1;35(19):E976–80.
20. Wen CP, Wai JP, Tsai MK, Yang YC, Cheng TY, Lee MC, *et al.* Minimum amount of physical activity for reduced mortality and extended life expectancy: a prospective cohort study. *Lancet*. 2011 Oct 1;378(9798):1244–53. doi: 10.1016/S0140-6736(11)60749-6
21. Rabiner A, Roach KE, Spielholz NI, Judson L. Characteristics of nursing home residents with contractures. *Phys Occup Ther Geriatr*. 1996;13(4):1–10. doi.org/10.1080/J148v13n04_01
22. Lam K, Kwan JSK, Kwan CW, Chi I. Factors associated with development of new joint contractures in long-term care residents. *J Am Med Dir Assoc*. 2022 Jan;23(1):92–97. doi: 10.1016/j.jamda.2021.05.036
23. Shimada T, Takemasa S, Hidaka M, Okiyama T, Inoue Y, Tomita Y, *et al*. Factors affecting development of contracture in hemiplegic patients. *BAMS* (Kobe). 1994 Dec 28;10:37–44. http://www.lib.kobe-u.ac.jp/handle_kernel/00423044

24. Ezeugwu V, Klaren RE, A Hubbard E, Manns PT, Motl RW. Mobility disability and the pattern of accelerometer-derived sedentary and physical activity behaviors in people with multiple sclerosis. *Prev Med Rep*. 2015 Apr 1;2:241–46. doi: 10.1016/j.pmedr.2015.03.007
25. Cleland C, Ferguson S, Ellis G, Hunter RF. Validity of the International Physical Activity Questionnaire (IPAQ) for assessing moderate-to-vigorous physical activity and sedentary behaviour of older adults in the United Kingdom. *BMC Med Res Methodol*. 2018 Dec 22;18(1):176. doi: 10.1186/s12874-018-0642-3
26. Chu AH, Ng SH, Paknezhad M, Gauterin A, Koh D, Brown MS, *et al*. Comparison of wrist-worn Fitbit Flex and waist-worn ActiGraph for measuring steps in free-living adults. *PLoS One*. 2017 Feb 24;12(2):e0172535. doi: 10.1371/journal.pone.0172535

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