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Back to sit transfer in aging: Motor planning impairments and functional abilities in frail aged adults

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Abstract. We studied age-related changes in motor-planning processes through the kinematic features of Sit-to-Stand (STS) and Back-to-Sit (BTS) transfers in aged adults. Our objective was to test the relationship between trunk angle during BTS transfer and functional level. The STS and BTS were analyzed with the Kinect motion capture system in sixty aged patients (33 women; mean age 84 ± 5). The statistical analysis was based on test-retest reliability, and we used Pearson coefficients to measure the robustness of the link between trunk angles and the timed-up and go (TUG) scores. We showed that patients with a lower functional level reached a smaller trunk angle during the BTS. Interestingly, this is even more pronounced in frail aged subjects. We suggest that this decrease of trunk angle during the BTS transfer signs an impairment of motor planning processes that should be checked in the context of frailty.

Key words: Frailty, motor-planning processes, transfers, aging, trunk position

Résumé. L'étude du transfert Assis-Debout au cours du vieillissement : Troubles de la planification motrice et capacités fonctionnelles des personnes âgées fragiles.

Il était question ici d'étudier l'impact du vieillissement sur les processus de planification motrice à travers les caractéristiques cinématiques des transferts assis-debout (STS) et debout-assis (BTS) chez des personnes âgées. Notre objectif était d'identifier une relation entre l'inclinaison de l'angle du tronc pendant le BTS et le niveau fonctionnel des sujets âgés. Les transferts STS et BTS étaient analysés à partir du système de capture du mouvement Kinect chez 60 patients âgés (33 femmes ; moyenne d'âge de 84 ± 5). L'analyse statistique était basée sur un test-retest de fiabilité et nous avons utilisé le coefficient de Pearson afin de mesurer la robustesse du lien entre les angles du tronc pendant les transferts et le score obtenu par les participants lors du test fonctionnel du Timed Up and Go (TUG). Les résultats montrent que les patients qui atteignent un faible niveau fonctionnel sont également ceux qui ont un plus petit angle d'inclinaison du tronc pendant le BTS. D'une manière intéressante, cette corrélation est beaucoup plus marquée chez les personnes âgées fragiles. Nous suggérons que cette diminution de l'angle d'inclinaison du tronc pendant le BTS est un marqueur pertinent d'un trouble de planification motrice. Ce paramètre devrait être systématiquement contrôlé dans un contexte de fragilité.

Mots clés : Fragilité, processus de programmation motrice, transferts, vieillissement, position du tronc

1 Introduction

Aging is often accompanied by declines in physical functions, which diminish quality of life, functional independence and abilities to perform daily tasks. The frailty syndrome involves a physiological decline leading to decreased reserves and resistances to stressor events (Chen *et al.*, 2014; Clegg *et al.*, 2013; Lipsitz, 2002). Fried and colleagues proposed five criteria to identify frailty syndrome mainly based on the physical abilities of aged adults: handgrip strength, exhaustion, gait speed, weight loss and physical activity (Fried *et al.*, 2001). This condition is due not only to muscle weakness and reduced endurance (Morley *et al.*, 2014), but also to other factors concerning the organization of movement. The realization of action requires early neuronal processes to plan and program this action (Bastian *et al.*, 1996; Harris & Wolpert, 1998; Wolpert & Ghahramani, 2000). Several studies have reported impairment of these processes in aging. One study investigated age-related changes in action simulation and action planning tasks. Healthy aged subjects showed impaired ability to mentally simulate rising from the floor sequences and to perform mental rotation tasks (Saimpont *et al.*, 2009, 2010). The authors underlined longer response times and higher error rates in the tasks described above, and suggested that aging involves a loss of motor planning ability in this kind of complex motor sequence.

Shorter movements, such as Sit-To-Stand (STS) and Back-To-Sit transfers (BTS), could also involve a high level of planning processes to adequately regulate muscle recruitment. These complex motor tasks were studied in aged adults in order to evaluate the effects of aging on motor planning processes by investigating the kinematics features of body motions during the STS and BTS in non-pathological aging. One study found no age-related changes in trunk angles during the STS and BTS. However, they noted an increase in BTS duration, which was explained by more cautious behavior in elderly subjects when they moved backwards without visual feedback, and probably by a greater difficulty to counter gravitational forces in this direction (Mourey *et al.*, 1998). Another study found greater trunk angles in young subjects than in elderly subjects. Interestingly, this age-related change was only seen during the BTS transfer. The authors interpreted this lack of trunk titling as non-optimal behavior related to changes in motor planning processes (Dubost & Beauchet, 2005). In view of these conflicting results from the literature, the question of impaired motor planning processes during STS and BTS transfers in the aged remains open. Nonetheless, both papers highlighted a greater difficulty of aged subjects to perform the BTS transfer.

As we noted above, aging processes could lead to a state of frailty. It is now well-documented that frailty disturbs motor activities of daily life. To assess this aspect of aging in our study, we analyzed transfer kinematics at the functional level in aged participants. Our aims were first (i) to assess the relationship between trunk angle during both transfers and the functional level of the aged participants and second (ii) to determine the strength of this relationship in frail aged subjects compared with non-frail aged subjects. We hypothesized that (1) this relationship would be highlighted only for the BTS transfer and that (2) it would characterize the frail population only.

2 Methods

2.1 Recruitment of participants, study design and description of tests

In this cross-sectional study, 60 subjects, who lived at home and were aged 70 years and older, were recruited from a geriatric day-hospital. The inclusion criteria were age at least 70 years old and being able to understand and follow the instructions related to the functional assessment. The exclusion criteria were severe cognitive impairment (affecting comprehension and communication abilities), an untreated orthopaedic disease, a severe malignant or non-malignant disease, a neurological disorder (including stroke and Parkinson syndrome), a severe muscular or rheumatologic disease, a severe or non-stabilized cardiovascular or respiratory disease. All the subjects were able to hear and see adequately. At inclusion, participants' anthropometric data and health status, including age, sex, and fall history in the previous 6 months, were collected. Finally, 33 females and 27 males aged 84 ± 5.2 years were recruited (table 1).

The functional evaluation was performed by the physiotherapist according to a defined protocol. This evaluation session included both the Gait Speed (GS) (Guralnik *et al.*, 2000) and the TUG (Podsiadlo & Richardson, 1991) tests. The GS and TUG were carried out in order to register the gait speed and the time to perform the TUG respectively for each participant. The GS consisted in walking 10 m at normal speed without human assistance. The speed was computed from the time taken to walk the distance and reported in meters per second. A threshold for frailty was a score under 0.65 m/s (Fried *et al.*, 2001). This threshold for the GS test allowed us to identify, *a posteriori*, two categories of participants (Non-Frail and Frail). Participants with GS score under 0.65 m/s were included in the Frail Group (FG_{GS}); those with scores above 0.65 m/s were included in the Non-Frail Group (NFG_{GS}) (table 1). The TUG test is commonly used to assess mobility and stability in elderly people. This test consists in standing up from a chair, walking three meters, turning round and coming back to sit on the same chair. Based on the TUG test, the STS and BTS transfers were recorded at the beginning of the experimental session, by using the Kinect motion capture system. In order to measure the test-retest reliability of the trunk angles measurements, participants were asked to perform two TUG tests consecutively. All the included participants were able to perform the TUG tests and the GS test wearing their usual shoes and without human aid.

Because it was a cross-sectional, observational study with no modification in the usual management of patients in the geriatric day-hospital, no written consent of the subjects was necessary.

2.2 Experimental procedure

All STS and BTS transfers were conducted in a similar environmental setting for all subjects using the same standard chair with armrests with the following characteristics: backrest height: 38 cm, armrest height: 60 cm and total chair height: 76 cm (Fig. 1). Each participant performed both the STS and the BTS during the TUG sequence, which allowed us to assess these transfers in a

Table 1. Demographics and performance described through mean and SD, for different functional evaluations, Gait Speed (GS) and Timed Up and Go test (TUG) in the complete sample of participants and for each group: Non-Frail Group (NFG_{GS}) and Frail Group (FG_{GS}) classified according to a GS threshold fixed at 0.65 m/s (Fried *et al.*, 2001).

		Groups established from threshold GS (< 0.65 m/s)	
	Elderly participants ($n = 60$)	FG_{GS} ($n = 35$)	NFG_{GS} ($n = 25$)
Gender	33	18	15
Female	27	17	10
Male			
Age (years)	84 ± 5.2	82.6 ± 4.7	85.8 ± 5.2
Mean ± SD	71–95	72–91	71–95
Range			
TUG (seconds)	15.53 ± 4.95	12.89 ± 2.56	19.21 ± 5.16
Mean ± SD	7.35–35.57	7.35–17.7	11.75–35.57
Range			
Gait speed (m/s)	0.67 ± 0.17	0.79 ± 0.1	0.51 ± 0.08
Mean ± SD	0.34–1.1	0.67–1.1	0.34–0.64
Range			
STS	21.82 ± 7.25	22.02 ± 7.65	21.68 ± 7.06
Mean ± SD	5.90–42.20	5.90–42.20	7.82–36.17
Range			
BTS	25.58 ± 10.7	24.37 ± 12.61	26.45 ± 9.36
Mean ± SD	−3.89–54.25	−3.89–48.29	15.33–54.25
Range			

relatively ecological context. The participants were free to use the armrests during the STS and BTS.

Half of the participants performed two TUG tests to allow the motion capture of two STS and BTS, thus enabling us to calculate the test-retest reliability of the measurement so as to determine the test reliability of this system in a rehabilitation context. The portable motion capture system was positioned at a distance of 2.5 m from the chair with a tilt angle of 20°. This system requires neither calibration nor set markers and uses a Kinect sensor, which extracts several skeletal points from the participant's motion. For our analysis, we focused on trunk movement, which is captured accurately by this sensor (Clark *et al.*, 2012, 2013). Two spatiotemporal parameters were computed; the maximal trunk angle reached by participants during the STS and BTS transfers. These maximal trunk angles, computed in the sagittal plane, were measured in degrees between the trunk axis and the vertical axis (Fig. 1).

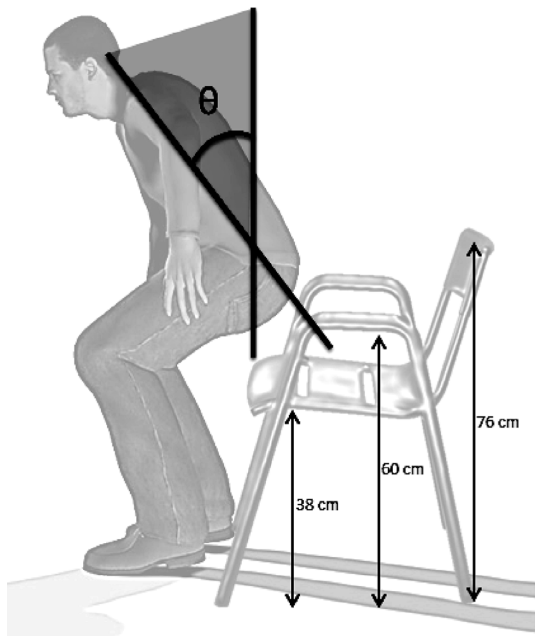

Fig. 1. Sit-to-stand analysis. The theta angle "θ", schematized on the figure, is extracted between the vertical axis and the trunk axis.

2.3 Statistical analysis

2.3.1 Test-retest reliability

Two motion sequences (then two TUG tests) were captured at the beginning of the test sessions. The 2-way intraclass correlation coefficient (ICC) was calculated to assess relative reliability of the maximal trunk angle measurement. An ICC greater than 0.7 was considered good (Weir, 2005).

Standard error of measurement (SEM) was used to test absolute reliability and to represent the absolute error of a measurement. The following formula was used: $\mathrm{SEM} = \mathrm{SD}^2 \times \sqrt{(1 - \mathrm{ICC})}$, where SD is the standard

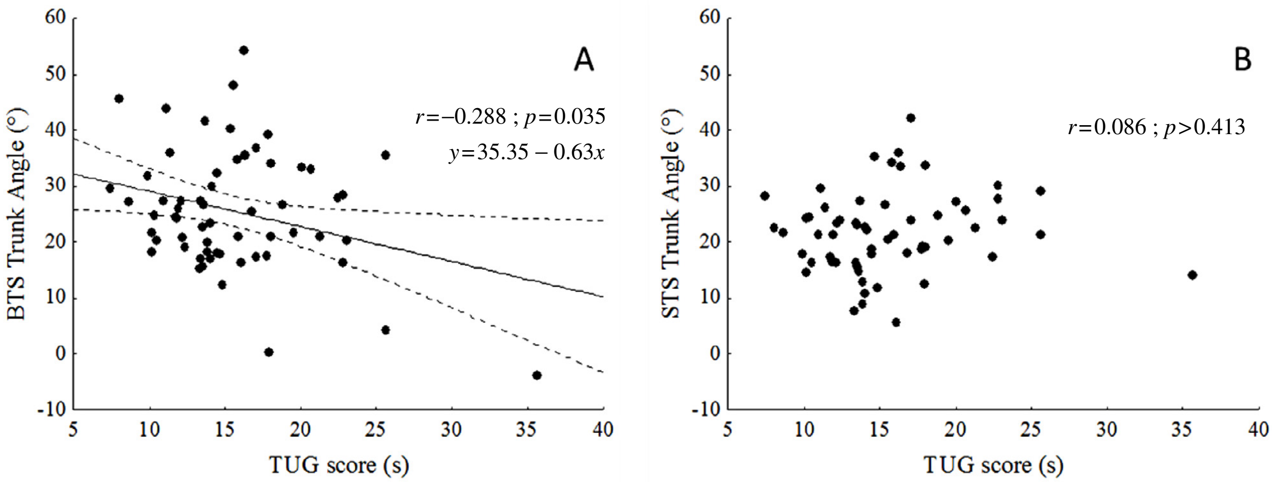

Fig. 2. Correlations of maximal trunk angles **(A)** during BTS transfer and TUG score **(B)** during STS transfer and TUG score, in the complete sample.

deviation of the 'maximal trunk angle' measurement (Weir, 2005).

A Minimal Detectable Change (MDC) allowed us to define a significant threshold beyond which the clinical changes can be considered important for the patient. It defines the absolute change in trunk angles (in degrees) that is not due to variations in the measurement maximal trunk angles. It was computed using the formulae: $\text{MDC} = \text{SEM} \times 1.96 \times \sqrt{2}$.

2.3.2 Relationships between trunk angles and TUG scores

Distribution normality and homogeneity of the variances were verified before the parametric tests were applied. As these conditions were verified, in the whole sample of patients and in the FG_{GS} and NFG_{GS} groups, we used Pearson coefficients to measure the robustness of the link between trunk angles and TUG scores, using an alpha level of 5%.

3 Results

3.1 Test-retest reliability

The ICCs of maximal trunk angles during the STS and BTS were greater than 0.7, which can be considered good. The STS ICC was 0.744 (Confidence interval: 0.529–0.869) and the BTS ICC was 0.727 (Confidence interval: 0.435–0.87). The SEM was equal to 3.6° and 5.5° for the STS and BTS, respectively. The associated MDC was equal to 10.0° for the STS trunk angle and 15.3° for the BTS trunk angle.

3.2 Trunk Angles and functional capacities in the complete sample.

The TUG scores and Gait speeds were plotted against trunk angles. The only significant correlation was found between BTS trunk angles and TUG scores. The Pearson coefficient showed a negative correlation ($r = -0.28$, $p = 0.035$, Fig. 2.A). There were no other significant correlations in this whole sample of patients (all the $r < 0.11$; all the $p > 0.413$). Interestingly, STS trunk angles did not correlate with TUG scores (Fig. 2.B).

3.3 Comparison of non-frail and frail subjects

The GS threshold fixed at 0.65 m/s allowed us to identify two subgroups in the complete sample: the NFG_{GS} ($n = 25$) had an average age of 85.8 ± 5.2 years and the FG_{GS} ($n = 35$) an average age of 82.6 ± 4.7 years, showing a significant age difference ($t(54) = -2.38$, $p = 0.02$).

A significant correlation was found between the TUG score and BTS trunk angle in the FG_{GS} ($r = -0.41$ and $p = 0.045$). In the NFG_{GS}, the relationship between these two variables was not significant ($r = -0.1$ and $p = 0.581$). These data are shown in Figure 3.

BTS trunk angles, TUG scores and GS scores in the FG_{G} were plotted on a 3D scatterplot. As we can see in Figure 4, the plane tilt seems to be more related to the TUG scores rather than the fluctuation of gait speed scores. The plane equation (P) was:

$$(\text{P}) : -1.063x - 8.062y - 1z + 49 = 0 \quad (1)$$

where "x" is the Gait Speed; "y" is the TUG score; "z" is the BTS trunk angle.

The director coefficient of the "y" variable (TUG score) is 8 times higher than both of the others. In this 3-variable relationship, which includes the BTS trunk angle, the TUG score had the greatest impact on total variance.

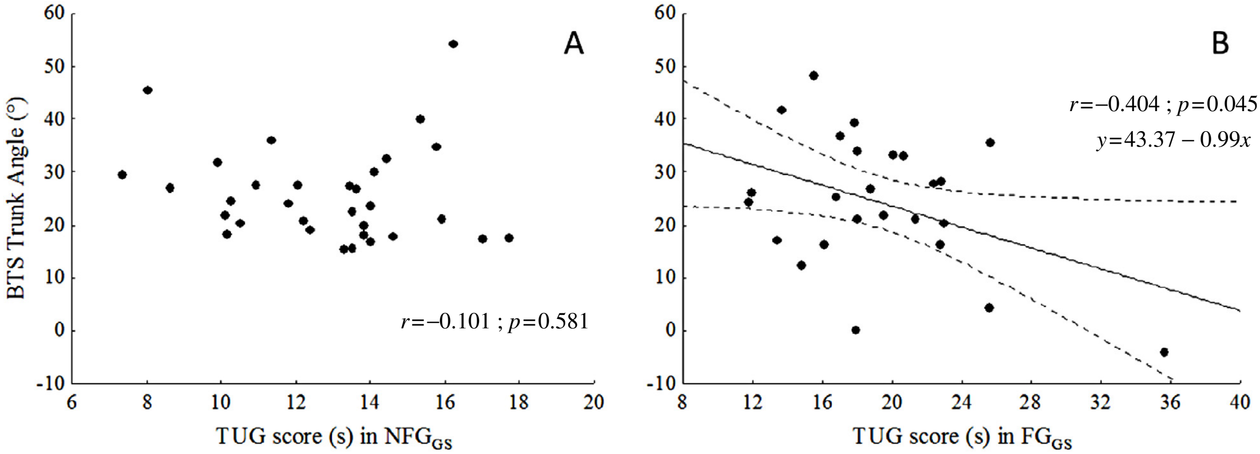

Fig. 3. Correlations of maximal trunk angles during BTS and TUG score **(A)** in non-frail group (NFG_{GS}) and **(B)** in frail group (FG_{GS}).

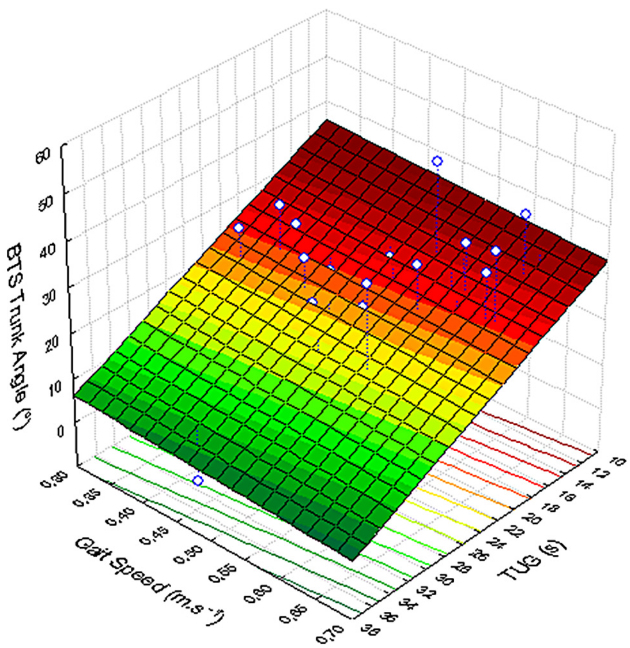

Fig. 4. Relationships between 3 variables (BTS Trunk Angle, TUG and Gait speed) represented in 3D scatter plot in the FG_{GS}.

4 Discussion

The aims of this study were to determine the relationship between maximal trunk angles during both transfers and the functional level of the aged participants, and to analyze the effect of frailty on these relationships. The first analysis concerned the whole sample of patients and revealed a weak -but significant- relationship between TUG scores and BTS trunk angles. Interestingly, this was not the case when the STS scores were plotted against TUG scores in the same sample.

These first results suggest that for aged subjects the BTS transfer is more challenging than the STS transfer, whether the subjects are frail or not. The study highlighted that patients with the lowest functional level reached the lowest trunk angle during the BTS.

From a functional point of view, the BTS transfer is more complex than the STS because it has to be performed in the absence of visual information. Consequently the end of the movement is more difficult to estimate (Kralj *et al.*, 1990). This result could be interpreted as a transition towards more cautious behavior in our sample of patients, which is in accordance with the literature about this transfer in aged subjects. Indeed, several papers showed (i) increased BTS duration compared with STS duration in aged subjects (Kerr *et al.*, 1997; Mourey *et al.*, 1998) and (ii) a greater impairment of the kinematic features of BTS movement organization compared with STS movement organization, by studying shoulder velocity profiles and trajectories (Dubost & Beauchet, 2005). Altogether, these results support the notion that dealing with gravitational force is more challenging in BTS movement for aged subjects, probably because of the difficulty to accurately counter this vertical force in a dynamic balance task. This phenomenon has already been highlighted in young individuals in a laboratory context (Papaxanthis *et al.*, 2003).

Interestingly, determining the frailty state according to frailty criteria (gait speed threshold of 0.65 m/s), in our sample of patients revealed only one significant correlation for the FG_{GS}, and that was between TUG scores and BTS trunk angles. Indeed, for these patients, we found that higher TUG scores were associated with lower maximal trunk angles during the BTS, and vice versa (Fig. 3). In terms of movement planning, this result showed that non-optimal processes mainly affected the frailer patients of our sample. Consequently, we propose that this parameter should be used more often to ascertain a second level of frailty than to spot the beginning of a decline in motor automatisms. Indeed, in a clinical context, massive impairment of motor automatism is often described as "backward disequilibrium" (Manckoundia, Mourey, *et al.*, 2007), and is often associated with the "psychomotor disadaptation syndrome" (Manckoundia, Pérennou, *et al.*, 2007). We propose that the early detection of this impairment in motor planning, using BTS trunk angle measurements, could be useful as it would improve patients' outcomes through the earlier initiation of rehabilitation programs.

Moreover, the MDC score (see results section) allows us to propose a frailty threshold for the BTS trunk angle that could be used in the follow-up of patients: a decrease of 15° in this angle can be considered worrisome and should trigger the implementation of rehabilitation.

As we mentioned in the results section, the covariation plane between TUG scores, GS scores and BTS trunk angles seemed to be more tilted because TUG scores and BTS trunk angles rather than GS scores. We found that GS scores did not fluctuate as a function of the two other variables. It might be not surprising to report that the BTS trunk angle has a stronger connection with the TUG scores than with GS scores, because this transfer is embedded in the TUG test itself. Clearly, a less optimal BTS transfer (*i.e.* a reduced angle) would induce an increase in TUG duration. At the same time, we may conclude from this observation that the impairment of motor planning processes does not affect gait speed, even in the frailest patients. From a clinical point of view, these results warrant the use of the TUG test to highlight these alterations in movement organization. From a fundamental point of view, it is interesting to note that some impairment in motor planning does not have major consequences on locomotors activity. We speculate that this could be explained by the high degree of repetition of this activity in daily life, even in frail patients, which could lead to the high-frequency updating of internal models that control this action (Wolpert & Flanagan, 2001).

We have to note a potential limitation of this work. The motion changes in STS and BTS could appear for two main reasons: (i) modifications in motor planning processes and/or (ii) increased musculoskeletal stiffness (especially in lumbar-pelvic joints). We did not measure the main ranges of motions in our aged participants, and this could therefore be a potential confounding factor. Nevertheless, we have to point out that the results of the present study clearly showed different behavior during BTS compared with STS. In the knowledge that motor-planning in BTS is different from that in STS (Papaxanthis *et al.*, 2003), it is more likely that the first hypothesis is correct.

To conclude, our results show that impairment in motor-planning processes, noticeable during the BTS transfer, is linked to functional abilities in frail aged subjects. A decrease in BTS trunk angle greater than 15° can be considered clinically worrisome, and should trigger the implementation of rehabilitation.

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Bibliography

Bastian, A.J., Martin, T.A., Keating, J.G., & Thach, W.T. (1996). Cerebellar ataxia: abnormal control of interaction torques across multiple joints. *Journal of Neurophysiology*, *76* (1), 492–509.

Chen, X., Mao, G., & Leng, S.X. (2014). Frailty syndrome: An overview. *Clinical Interventions in Aging*, *9*, 433–441.

Clark, R.A., Bower, K.J., Mentiplay, B.F., Paterson, K., & Pua, Y.H. (2013). Concurrent validity of the Microsoft Kinect for assessment of spatiotemporal gait variables. *Journal of Biomechanics*, *46* (15), 2722–2725.

Clark, R.A., Pua, Y.H., Fortin, K., Ritchie, C., Webster, K.E., Denehy, L., & Bryant, A.L. (2012). Validity of the Microsoft Kinect for assessment of postural control. *Gait & Posture*, *36*(3), 372–377.

Clegg, A., Young, J., Iliffe, S., Rikkert, M.O., & Rockwood, K. (2013). Frailty in elderly people. *The Lancet*, *381*, 752–762.

Dubost, V., Beauchet, O Manckoundia, P., Hermann, F., Mourey, F., (2005). Decreased trunk angular displacement during sitting down: An early feature of aging, *Physical Therapy, 85*, 404–412.

Fried, L.P., Tangen, C.M., Walston, J., Newman, A.B., Hirsch, C., Gottdiener, J., *et al.* (2001). Frailty in older adults: Evidence for a phenotype. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *56* (3), M146–M157.

Guralnik, J.M., Ferrucci, L., Pieper, C.F., Leveille, S.G., Markides, K. S., Ostir, G.V., *et al.* (2000). Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *55* (4), M221–M231.

Harris, C.M., & Wolpert, D.M. (1998). Signal-dependent noise determines motor planning. *Nature*, *394* (August), 780–784.

Kerr, K., White, J., Barr, D., & Mollan, R. (1997). Analysis of the sit-stand-sit cycle in normal subjects movement. *Clinical Biomechanics*, *12* (4), 236–245.

Kralj, A., Jaeger, R.J., & Munih, M. (1990). Analysis of standing up and sitting down in humans: definations and normative data presentation. *Journal of Biomechanics*, *23*, 1123–1138.

Lipsitz, L.A. (2002). Dynamics of stability: the physiologic basis of functional health and frailty. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *57* (3), B115–B125.

Manckoundia, P., Mourey, F., Tavernier-Vidal, B., & Pfitzenmeyer, P. (2007). Syndrome de désadaptation psychomotrice. *La Revue de Médecine Interne*, *28* (2), 79–85.

Manckoundia, P., Pérennou, D., Pfitzenmeyer, P., & Mourey, F. (2007). La rétropulsion du sujet âgé: mise au point sur un symptôme grave et proposition d'une échelle pour une évaluation quantifiée. *Revue de Medecine Interne*, *28* (4), 242–249.

Morley, J.E., von Haehling, S., Anker, S.D., & Vellas, B. (2014). From sarcopenia to frailty: A road less traveled. *Journal of Cachexia, Sarcopenia and Muscle*, *5* (1), 5–8.

Mourey, F., Pozzo, T., Rouhier-Marcer, I., & Didier, J.P. (1998). A kinematic comparison between elderly and young subjects standing up from and sitting down in a chair. *Age and Ageing*, *27* (2), 137–146.

Papaxanthis, C., Dubost, V., & Pozzo, T. (2003). Similar planning strategies for whole-body and arm movements performed in the sagittal plane. *Neuroscience*, *117* (4), 779–783.

Podsiadlo, D., & Richardson, S. (1991). The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society*, *39* (2), 142–148.

Saimpont, A., Mourey, F., Manckoundia, P., Pfitzenmeyer, P., & Pozzo, T. (2010). Aging affects the mental simulation/planning of the "rising from the floor" sequence. *Archives of Gerontology and Geriatrics*, *51* (3), e41–e45.

Saimpont, A., Pozzo, T., & Papaxanthis, C. (2009). Aging affects the mental rotation of left and right hands. *PloS One*, *4* (8), e6714.

Weir, J.P. (2005). Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association*, *19* (1), 231–240.

Wolpert, D.M., & Flanagan, J.R. (2001). Motor prediction. *Current Biology*, *11*, R729–R732.

Wolpert, D.M., & Ghahramani, Z. (2000). Computational principles of movement neuroscience. *Nature Neuroscience*, *3*, 1212–1217.