Development of a new assessment tool for cervical myelopathy using hand tracking sensor – Part 2: normative values

---

Authors:

M Abdulhadi Alagha (Please keep the M)
Academic Orthopaedics, Trauma and Sports Medicine, The University of Nottingham, Queen's Medical Centre, Nottingham NG7 2UH, UK

Mahmoud A Alagha
Medical, Veterinary and Life Sciences College, University of Glasgow
Dental Hospital, Glasgow G2 3JZ, UK

Eleanor Dunstan
Centre for Spinal Studies and Surgery, Queen's Medical Centre, Nottingham NG7 2UH, UK

Olaf Sperwer
VRmed Ltd., Rosewood House, Radcliffe on Trent, Nottingham NG12 2BQ, UK

Kate A Timmins
School of Sport & Exercise Science, University of Lincoln, Lincoln LN6 7TS, UK

Bronek M Boszczyk (Correspondence)
Centre for Spinal Studies and Surgery, Queen's Medical Centre, Nottingham NG7 2UH, UK
E-mail: bronek.boszczyk@nuh.nhs.uk

Ethical Approval: Obtained by The University of Nottingham.
Ethics Reference No: F12032015 SoM Spinal Surg

Funding: The study was funded by Nottingham University Hospitals (Spine Research). Bbraun and VRmed supported the design of the software. The companies had no role in the design, interpretation or reporting of the study. The authors declared no conflict of interest.

Abstract

Purpose To set a baseline measurement of the number of hand flexion-extension cycles and analyse the degree of motion in young healthy individuals, measured by Leap Motion Controller (LMC), besides describing gender and dominant hand differences.

Methods Fifty healthy participants were asked to fully grip-and-release their dominant hand as rapidly as possible for a maximum of three minutes or until subjects fatigued, while wearing a non-metal wrist splint. Participants also performed a 15-second grip-and-release test. An assessor blindly counted the frequency of grip-and-release cycles and magnitude of motion from the LMC data.

Results The mean number of the 15-second G-R cycles recorded by LMC was: 47.7±6.5 (test 1, LMC); and 50.2±6.5 (test 2, LMC). In the 3-minute test, the total number of hand flexion-extension cycles and the degree of motion decreased as the person fatigued. However, the decline in frequency preceded that of motion's magnitude. The mean frequency of cycles per 10-second interval decreased from 35.4 to 26.6 over the 3 minutes. Participants reached fatigue from 59.38 seconds; 43 participants were able to complete the 3-minute test.

Conclusions Normative values of the frequency of cycles and extent of motion for young healthy individuals, aged 18-35 years, are provided. Future work is needed to establish valued in a wider age range and in a clinical setting.

Key Words: Cervical Myelopathy, Virtual Reality, Leap Motion, Grip and release test, Gender differences, Dominant hand differences

Introduction

The grip-and-release (G-R) test, in which patients are asked to flex and extend their fingers as rapidly as possible, is used to detect neurological deterioration in the hand which is associated with cervical myelopathy. The initial test, developed by Ono and coworkers [10], counts the number of full flexion-extension cycles within 10 seconds. They found that healthy individuals registered 20 cycles within the 10-second period, in contrast to myelopathic patients, whose flexion-extension cycles were remarkably deficient, heavy and slow. Hosono and colleagues [6] extended the G-R test to 15 seconds and demonstrated the test to be statistically reliable and valid. However, the necessity of a digital camera and the time cost of data analysis limit its practicality in clinical environments. For this reason, the feasibility of using a virtual reality sensor to assist in measuring the test is being explored.

The Leap Motion Controller (LMC) is a remote sensing, virtual reality hand sensor. The device has been shown to be an accurate and robust sensor [15], and its validity and reliability to measure the 15-second G-R test is reported in our previous article. This study extends the proof of concept work by reporting normative values for young healthy individuals regarding both the frequency of cycles as well as the magnitude of motion during a 15-second test and a 3-minute test.

Materials and methods

The aim of this study is to set normative values using the LMC, which would be used as a benchmark for diagnosis in a clinical setting. The detailed study protocol has been published previously [1]. In brief, a total of 50 healthy participants between 18 and 35 years of age were recruited at a university, and asked to perform the G-R test in the presence of both an external video camera and the LMC. Participants used their dominant hand, pronated and splinted. Participants underwent two 15-second G-R tests followed by a 3-minute test (or to exhaustion), each separated by a 10-minute rest interval. The total number and magnitude of motion of cycles were counted from the LMC data output in increments of half cycles. A full magnitude of motion for a cycle was defined as full movement through 5 hand positions: there were 8 'motions' specified comprising movement from position 1 to position 5 and back again [1]. Magnitude of motion was measured as the number of motions in each cycle. Ethical approval was obtained by The University of Nottingham Ethics committee. The study was funded by Nottingham University Hospitals (Spine Research). Bbraun and VRmed supported the design of the software. The companies had no role in the design, interpretation or reporting of the study. The authors declared no conflict of interest.

<u>*Analyses:*</u>
Normative values for the 15-second test are given as means, SD, range and percentiles. The 3-minute test was divided into 10-second intervals for the purposes of data presentation. The number of participants at each time point was plotted on a survival curve. Cycle count data, but not magnitude of motion data, were normally distributed.

IBM SPSS for Macintosh version 22.0, and Microsoft Excel version 15.14 were used to analyse all data.

Results

Fifty individuals [Males: 27 (54%), Females: 23 (46%)] participated in the study. Participants' ages ranged from 19 to 34 years (Mean=24.24, SD=3.28). 46 were right-handed (92%), and four left-handed (8%). Three of the 4 left-handed participants were males.

<u>*Normative values:*</u>
The normative values for the 15-second test are presented in Table 1.

For the 3-minute test, the number of G-R cycles for each 10 second interval is displayed in **Fig1**. There was a sharp decline between 0 and 60 seconds, followed by a levelling off after 60 seconds. The mean magnitude of motion for each 10-second interval is shown in **Fig2**. There was approximately a constant decrease, ranging from a maximum average of 7.49 at T1 to a minimum average of 6.25 at T15. The number of cycles and magnitude of motion are plotted together in **Fig3**. The number of participants available at each time period can be seen in **Fig4.** 43 participants were able to grip-and-release their hand for three minutes. The earliest fatigue point was at T6 interval, precisely 59.38 seconds.

Table 1 Normative values for the 15-second Grip and Release test, measured by LMC

		Number of Cycles				Magnitude of Motion			
		Mean	**SD**	**Min**	**Max**	**Median**	**IQR**	**Min**	**Max**
Total Sample (n=50)		47.72	6.48	32	62.5	7.46	1.19	5.25	8
Gender	**Males (n=27)**	46.62	5.81	34.5	59	7.62	0.84	5.93	8
	Females (n=23)	49	7.12	32	62.5	7.09	1.4	5.25	8
Hand Dominance	**Right (n=46)**	48.02	6.44	32	62.5	7.46	1.19	5.64	8
	Left(n=4)	44.25	6.84	36.5	52.5	7.65	0.98	5.25	8

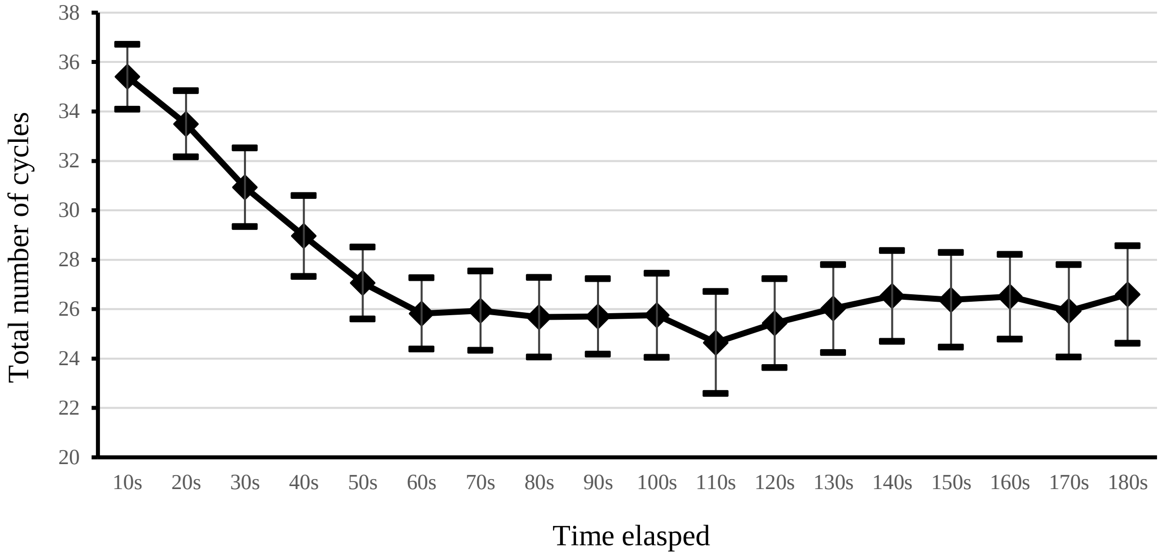

Fig1 Number of grip-and-release cycles per 10-second interval with (Mean with CI); showing a constant decline in the number of cycles till T6 due to physiological fatigue

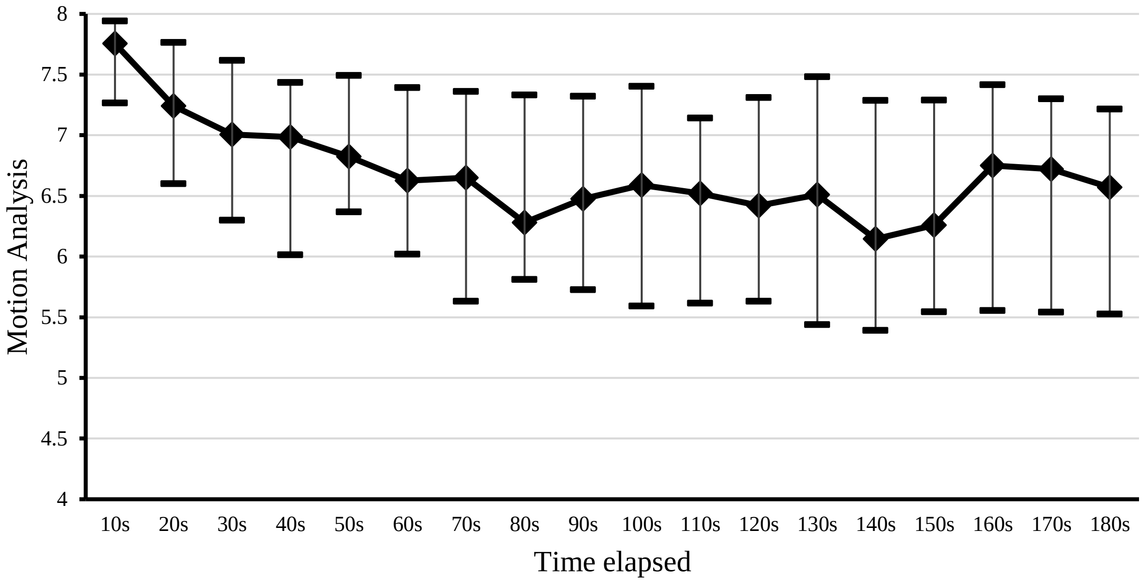

Fig2 Motion Analysis of grip-and-release cycles per 10-second intervals (Median with IQR); positions 2 to 5 were consistently reached but position 1 (fully extensions) was reliably reached during the first 10 seconds only

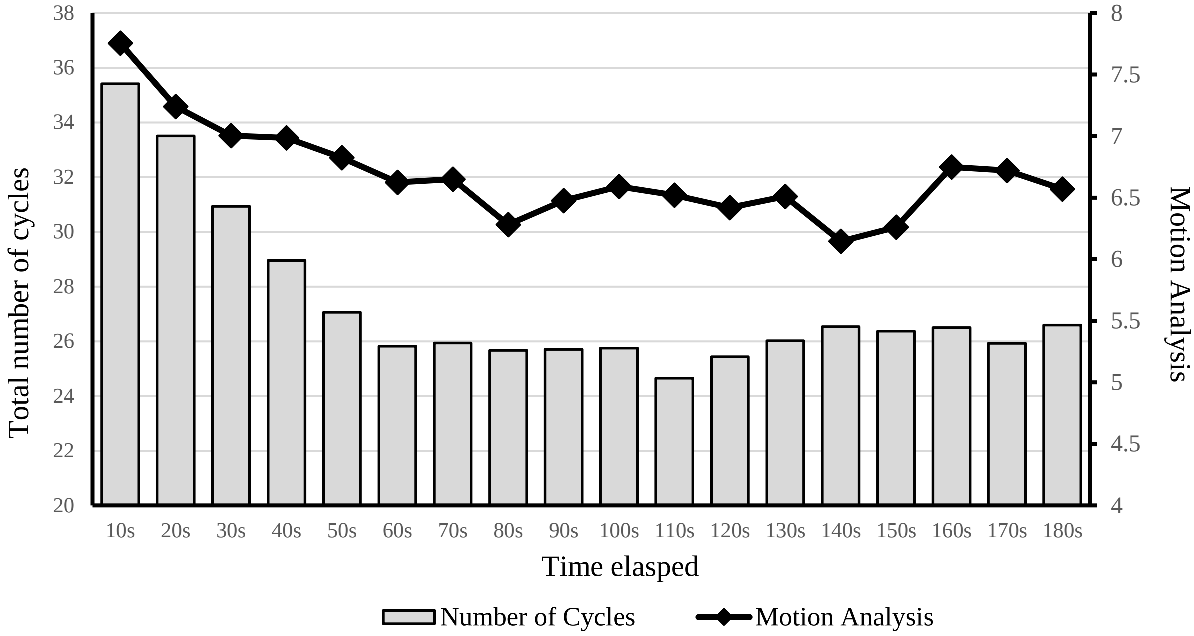

Fig3 Motion Analysis and the number of grip-and-release cycles per 10-second intervals. Overall, the decline in the number of cycles precedes that of the magnitude of motion

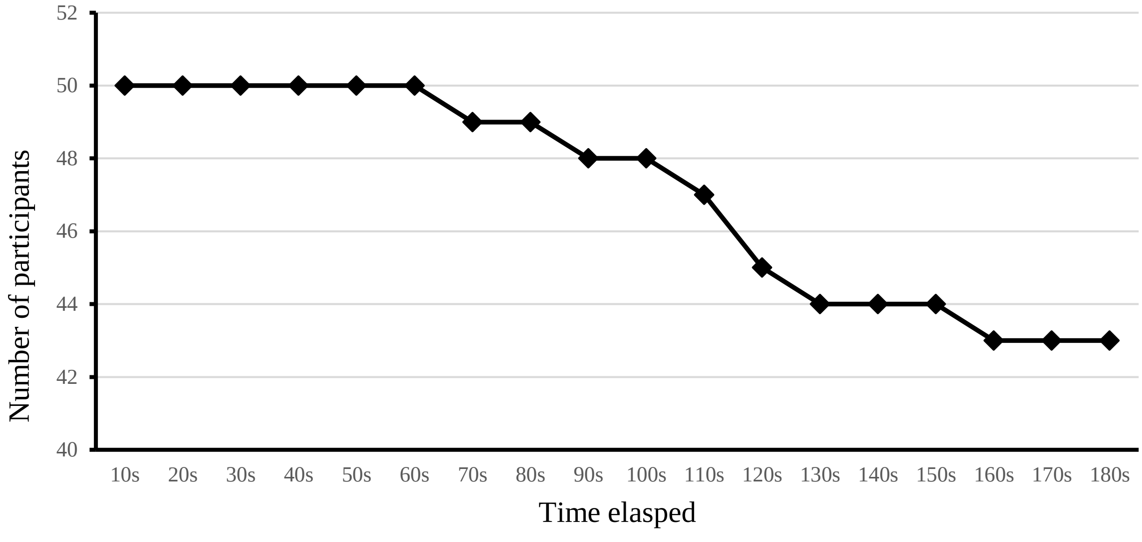

Fig4 Number of participants at each10-second interval

Sex Differences:
The number of cycles, motion magnitude and the number of participants at each time point with confidence intervals are shown in **Fig5**, **Fig6** and **Fig7**. There were no noteworthy sex differences (**Online Resource 1**). A total of 3 females (13%) fatigued before the end of the test, as compared to 4 males (15%).

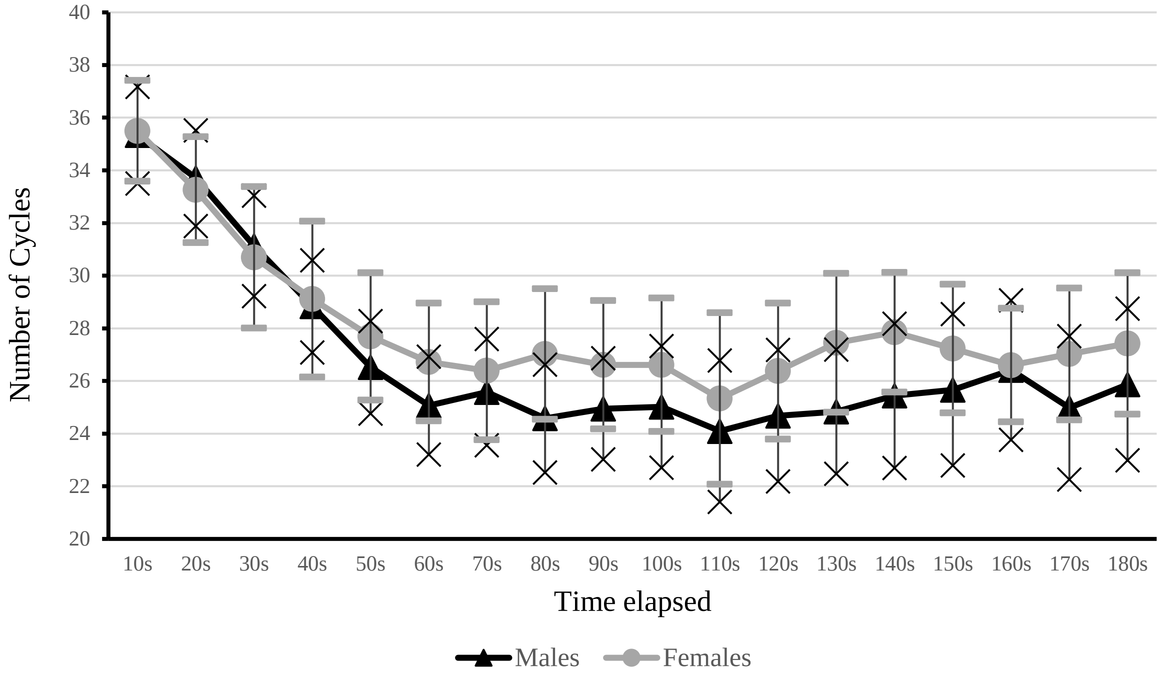

Fig5 Number of cycles per 10-second intervals according to gender (Mean with CI)

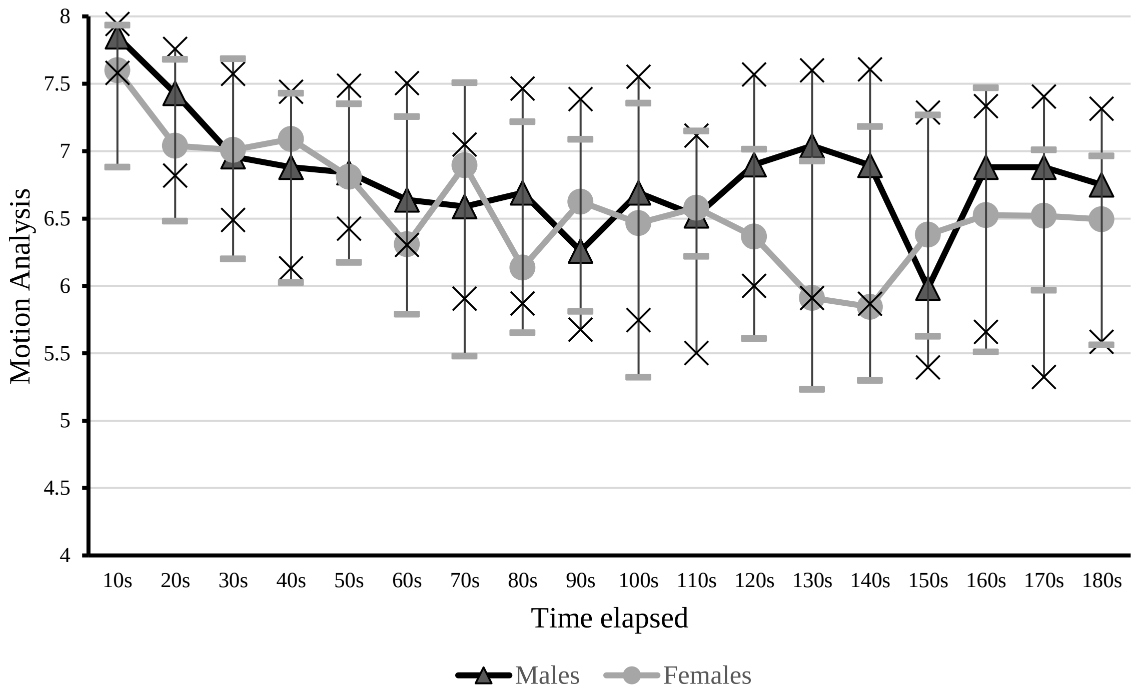

Fig6 Motion Analysis per 10-second intervals according to gender (Median with IQR)

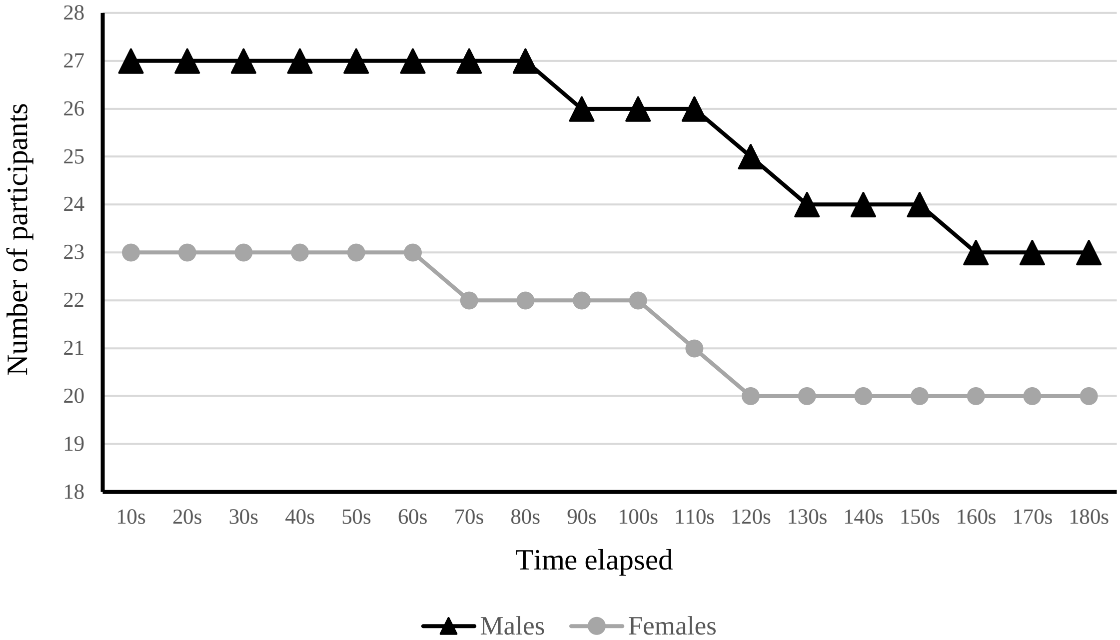

Fig7 Number of participants at each time-point by gender

Dominant Hand Differences:

Fig8 and **Fig9** show the number of cycles and magnitude of motion by handedness. Right-handed individuals appeared to achieve a higher number of cycles than left-handed subjects (**Fig8**) and possibly a lesser magnitude of motion (**Fig9**), especially towards the later stages of the test (full results in **Online Resource 2**). However, it should be noted there were only 4 left-handed participants.

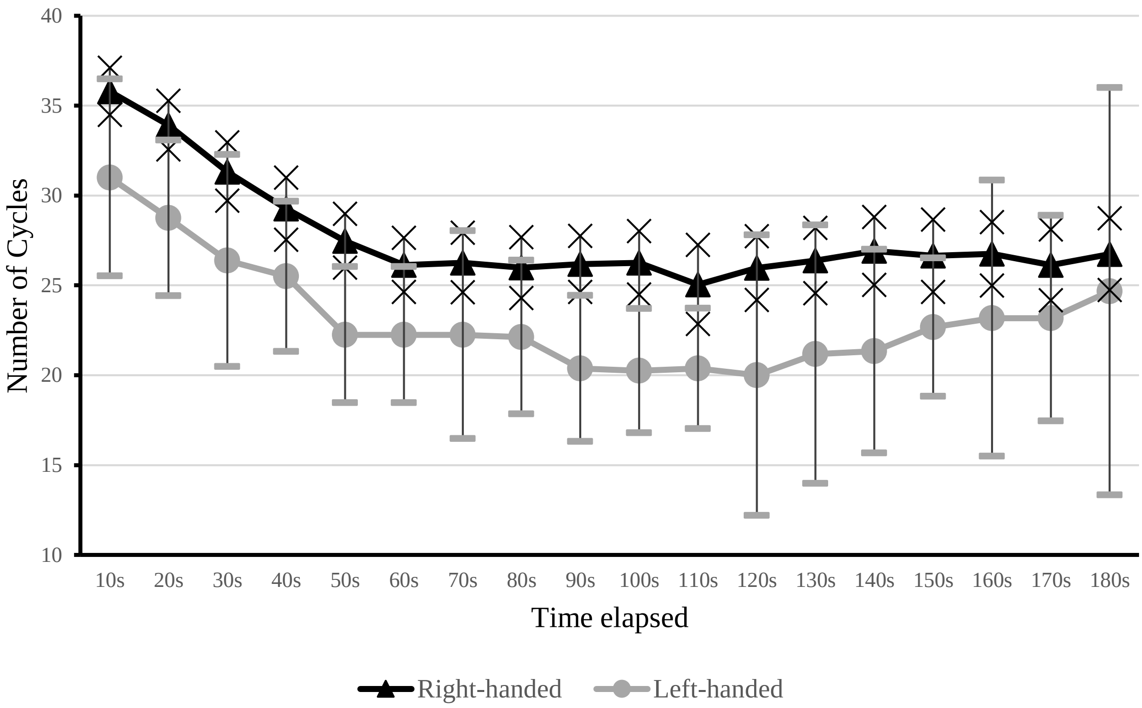

Fig8 Number of cycles at each time-point by dominant hand (Mean with CI)

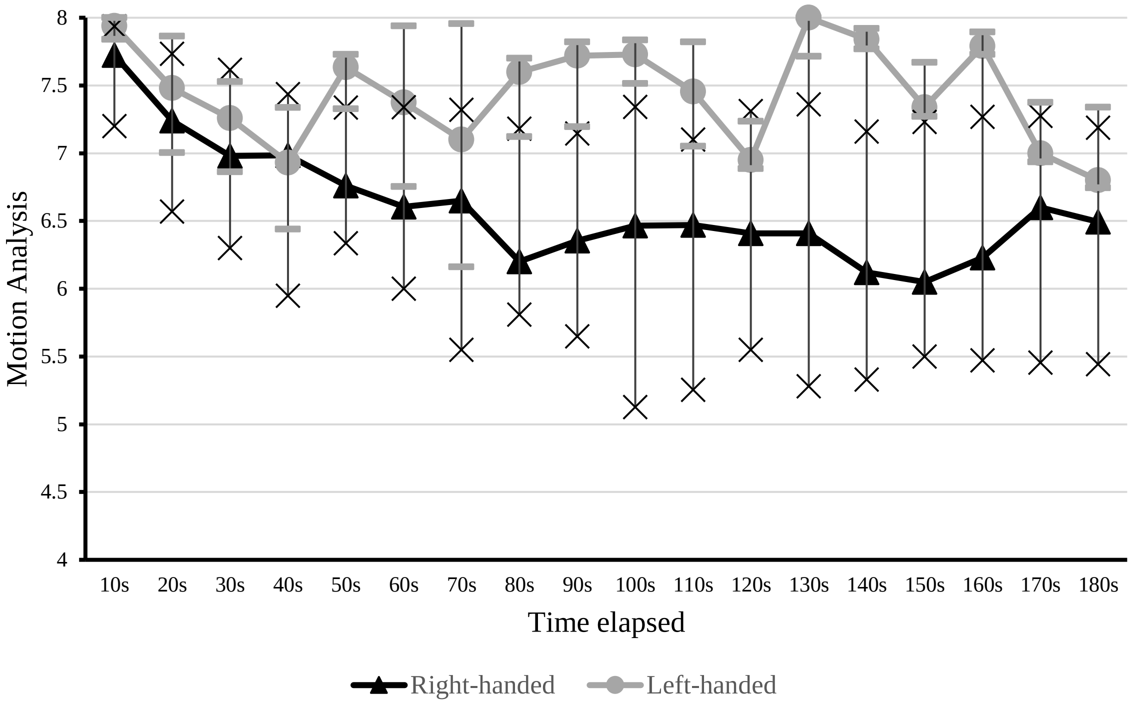

Fig9 Motion Analysis at each time-point by dominant hand (Median with IQR)

Discussion

This study described benchmark values for healthy individuals using the 15-second LMC G-R test (47.72±6.48), which were higher than Hosono et al's [6] figures (32.5±9). In the longer 3-minute test, the total number of hand flexion-extension cycles and the magnitude of motion were shown to decrease as the person fatigues. Values by sex and dominant hand were also reported. Overall, the frequency of cycles appeared to decline more rapidly than the extent of motion.

There was a steady decline in the frequency of G-R cycles from the onset of the test until 60 seconds. This mirrors the "Fatigue Phenomenon" described by Hosono et al. [6], which indicated a significant decrease with each succeeding 5-second interval of the 15-second G-R test in healthy individuals [6, 7]. The implication is that reduction in the number of cycles is due to the fatigue induced by the maximal effort enforced.

Additionally, the average number of cycles for the first 10-second interval was 35.41±4.73, which is greater than previous findings in Japanese adults: mean=22.0±5.7 [16], mean=26.0±6.7 [13] and mean=27.0±5.7 [14]. Ono et al [10] similarly reported that healthy individuals perform more than 20 grip-and-releases during a 10-second test. It should be noted, however, that previous studies included participants from wider age groups (20-79 years old), and a significant negative correlation between the frequency of the 10-second G-R and age has been reported [16]. It is therefore important that normative age group-specific values are investigated in future studies.

The magnitude of motion was similarly observed to fall as time progressed in the 3-minute test, and position 1 (full extension) appeared to be reliably attained in the first 10 seconds only. No previous studies have assessed the extent of G-R motion. Nonetheless, it is key to take the magnitude of motion into account when programming the LMC software as to what to measure as a G-R cycle. The decline in the magnitude of motion appeared to be less severe than the drop in the number of cycles.

Sex Differences:
There were no apparent differences between males and females regarding either the total number of G-R cycles or the magnitude of motion. These results contradict an earlier study, which found statistically significant differences in the number of cycles of the 10-second G-R test according to gender and age groups [16]. Again, this could be due to the different demographic profile of the samples used. Although, mean hand grip strength

in healthy adults is shown to be less in women than in men [3, 5]. Having said that, grip strength and G-R cycles are not necessarily measuring the same thing.

Dominant Hand Differences:

This study showed initial findings of G-R test data according to handedness. Although there was a very small number of left-handed participants (n=4), these initial findings are suggestive of a lower cycle frequency but slightly higher magnitude of motion. It could be conjectured that the two are related: in other words, a narrower magnitude of motion allows for a higher frequency of cycles amongst right-handed individuals. However, with such a small sample, it is not possible to confirm this. One out of the four left-handed subjects fatigued before the end point, which could explain the fluctuations seen in the frequency and motion magnitude charts.

In the literature, the evidence of grip strength differences according to hand dominance is conflicting. Massy-Westropp and others [9] found that hand grip strength was higher in the right hand, regardless of hand dominance. On the other hand, the 10% hand dominance rule indicating that the dominant hand has 10% more powerful grip than the non-dominant one [11], was shown in a review of ten studies to be true for right dominant subjects. Conversely, among left-handed people the findings were equivocal [2] and grip strength was similar in both hands [4, 12]. Again, though, grip strength and manual dexterity are different constructs.

This study represents the first step in establishing normative values which will inform the use of Virtual-Reality aided G-R tests in the clinical setting. However, a key limitation is the sample size, and the narrow age range of participants. The number of the cycles in the 10s G-R test were shown to be related to age, thus future studies should establish the normative values for all age groups, especially the 40-70 age group where myelopathy is the most prevalent [8]. The study was descriptive and not powered to detect differences by sex or handedness. As more data is collected in the future, it will be possible to explore, for example, sex and dominant hand differences using statistical comparisons. Further research is also planned to determine the effects of fatigue between the tests; 10-minute rests were used in this study for pragmatic reasons, but there is little evidence to confirm if this is sufficient. Data also needs to be collected from clinical groups, to gauge the extent of deterioration in cervical myelopathy patients.

Conclusion

This study further proves the concept of incorporating the LMC in the G-R test, by providing objective measures of manual dexterity, as is pertinent to the diagnosis of cervical myelopathy. Normative values for both the frequency of cycles and magnitude of motion are presented for young healthy individuals. As expected, the number of hand flexion-extension cycles and the degree of motion decreased as the person fatigued. However, the decline in frequency preceded that of motion magnitude. Future studies are needed to set benchmark values for all age groups, according to gender and hand dominance in both healthy and cervical myelopathic patients.

References:

1. Alagha MA, Alagha MA, Dunstan E, Sperwer O, Timmins KA, Boszczyk BM (2017) Development of a new assessment tool for cervical myelopathy using hand tracking sensor – Part 1: validity and reliability. European Spine Journal.
2. Bohannon RW (2003) Grip strength: a summary of studies comparing dominant and nondominant limb measurements. Percept Mot Skills 96(1):728–730. doi: 10.2466/pms.2003.96.3.728
3. Bohannon R, Peolsson A, Massy-Westropp N, Desrosiers J, Bear-Lehman J (2006) Reference values for adult grip strength measured with a Jamar dynamometer: a descriptive meta-analysis. Physiotherapy 92(1):11-15. doi: 10.1016/j.physio.2005.05.003
4. Crosby CA, Wehbe MA (1994) Hand strength: Normative values. The Journal of Hand Surgery 19(4):665-670. doi: 10.1016/0363-5023(94)90280-1
5. Günther C, Bürger A, Rickert M, Crispin A, Schulz C (2008) Grip Strength in Healthy Caucasian Adults: Reference Values. The Journal of Hand Surgery 33(4):558-565. doi: 10.1016/j.jhsa.2008.01.008
6. Hosono N, Sakaura H, Mukai Y, Kaito T, Makino T, Yoshikawa H (2008) A simple performance test for quantifying the severity of cervical myelopathy. Journal of Bone and Joint Surgery 90-B(9):1210-1213. doi: 10.1302/0301-620X.90B9.20459
7. Hosono N, Makino T, Sakaura H, Mukai Y, Fuji T, Yoshikawa H (2010) Myelopathy Hand: New Evidence of the Classical Sign. Spine 35(8):E273-E277. doi: 10.1097/BRS.0b013e3181c6afeb
8. Machino M, Imagama S, Ando K, Kobayashi K, Hida T, Ito K, Tsushima M, Matsumoto A, Tanaka S, Morozumi M, Ito K, Kato F, Nishida Y, Ishiguro N (2016) Prospective Comparison of Age- and Sex-Related Differences in Quantifiable 10-S Grip and Release and 10-S Step Test Results for Diagnosis of Cervical Spondylotic Myelopathy in 454 Patients with Cervical Spondylotic Myelopathy and 818 Asymptomatic Subjects. Spine (Phila Pa 1976). doi: 10.1097/BRS.0000000000001849
9. Massy-Westropp N, Gill T, Taylor A, Bohannon R, Hill C (2011) Hand Grip Strength: age and gender stratified normative data in a population-based study. BMC Research Notes 4(1):127-129. doi: 10.1186/1756-0500-4-127
10. Ono K, Ebara S, Fuji T, Yonenobu K, Fujiwara K, Yamashita K (1987) Myelopathy hand. New clinical signs of cervical cord damage. J Bone Joint Surg (Br) 69(2):215–219
11. Petersen P, Petrick M, Connor H, Conklin D (1989) Grip strength and hand dominance: challenging the 10% rule. Am J Occup Ther 1989 43(7):444-447. doi: 10.5014/ajot.43.7.444
12. Roberts H, Denison H, Martin H, Patel H, Syddall H, Cooper C, Sayer A (2011) A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. Age and Ageing 40(4):423-429. doi: 10.1093/ageing/afr051
13. Wada E, Yonenobu K, Fukui M, Hirota Y, Kikuchi S, Toyama Y, Kawakami M, Atsushi S (2003) Grip and Release Test (10 Seconds Test) in Healthy Volunteers and Cervical Myelopathy Patients-A Simple Bedside Test for the Assessment of Cervical Myelopathy. Cervical Spine Research Society:112-113. Available at: http://www.csrs.org/grip-and-release-test-10-seconds-test-in-healthy-volunteers-and-cervical-myelopathy-patients-a-simple-bedside-test-for-the-assessment-of-cervical-myelopathy/ [Accessed 21 Aug. 2016]
14. Wada E, Yonenobu K, Fukui M, Hirota Y, Kikuchi S, Toyama Y, Kawakami M, Seichi A (2004) Intraobserver Reliability of Grip and Release Test (10-Second Test) in Healthy Volunteers and Cervical Myelopathy Patients. Cervical Spine Research Society:261-263. Available at: http://www.csrs.org/intraobserver-reliability-of-grip-and-release-test-10-second-test-in-healthy-volunteers-and-cervical-myelopathy-patients/ [Accessed 21 Aug. 2016]
15. Weichert F, Bachmann D, Rudak B, Fisseler D (2013) Analysis of the Accuracy and Robustness of the Leap Motion Controller. Sensors 13(5):6380-6393. doi: 10.3390/s130506380
16. Yukawa Y, Nakashima H, Ito K, Machino M, Kanbara S, Kato F (2013) Quantifiable tests for cervical myelopathy; 10-s grip and release test and 10-s step test: standard values and aging variation from 1230 healthy volunteers. Journal of Orthopaedic Science 18(4):509-513. doi: 10.1007/s00776-013-0381-6