January 2022

Associations Between Handgrip Stength Asymmetry And Health Related Quality Of Life Among Canadian Adults: An Analysis Of The Canadian Health Measures Survey

Jessica Lembke

ASSOCIATIONS BETWEEN HANDGRIP STENGTH ASYMMETRY AND HEALTH RELATED QUALITY OF LIFE AMONG CANADIAN ADULTS: AN ANALYSIS OF THE CANADIAN HEALTH MEASURES SURVEY

by

Jessica Lembke
Bachelor of Science, University of North Dakota, 2022

A Thesis

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

For the degree of

Master of Science

Grand Forks, North Dakota

May

2022

Name: Jessica Lembke

Degree: Master of Science

This document, submitted in partial fulfillment of the requirements for the degree from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

DocuSigned by:
Grant Rhyan Tomkinson
Grant Tomkinson

DocuSigned by:
Tanis Walch
Tanis Walch

DocuSigned by:
Justin Lang
Justin Lang

This document is being submitted by the appointed advisory committee as having met all the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.

DocuSigned by:
Chris Nelson
Chris Nelson
Dean of the School of Graduate Studies

5/4/2022
Date

PREMISSION

Title Association Between Handgrip Strength Asymmetry and Health Related Quality of Life Among Canadian Adults: An analysis of the Canadian Health Measures Survey

Department Education, Health, and Behavior Studies

Degree Master of Science

In presenting this thesis in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the library of the University shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my thesis work, or in his absence, by the Chairperson of the department or the dean of the School of Graduate Studies. It is understood that any copying or publication or other use of this thesis or part thereof for financial gain shall not be allowed without my written permission. It is also understood that due to recognition shall be given to me and to the University of North Dakota in any scholarly use which may be made of any material in my thesis.

Jessica Lembke
05-05-2022

ACKNOWLEDGMENTS

I wish to express my sincere appreciation to the members of my advisory Committee for their tireless efforts and guidance during my time in the master's program at the University of North Dakota. Without their support I would not have been able to reach such a high level of learning.

To my wife Sydney and my friend Jesse

for always believing I can achieve anything.

And to my advisors Grant, Tanis, and Justin

for the endless learning opportunities and their abundance of knowledge.

Table of Contents

LIST OF TABLES

ABSTRACT

Background: Health related quality of life (HRQOL), a measure of perceived quality of health is significantly related to current and future health. Handgrip strength (HGS) asymmetry is an aspect of muscle function that can be measured using handheld dynamometry. While several studies have examined relationships between HGS asymmetry and HRQOL, few have used nationally-representative data, and none have used Canadian data. The aim of this study, therefore, was to examine the association between HGS asymmetry and HRQOL in a nationally-representative sample of Canadian adults.

Methods: A secondary analysis of cross-sectional data from cycles 5 and 6 (2016–17 and 2018–19) of the Canadian Health Measure Surveys (CHMS) dataset was performed for adults (aged 18–79 years). HGS asymmetry was calculated as the ratio between the maximum HGS scores for the strongest and weakest hands. HRQOL was measured using the Health Utility Index. Crude and covariate-adjusted logistic regression models were used to quantify the relationships between HGS asymmetry and HRQOL.

Results: This study showed that HGS asymmetry was significantly associated with poor HRQOL in Canadian adults. Relative to individuals without asymmetry, adults with ≥21% asymmetry had 1.80 (95%CI: 1.26–2.56) greater odds for poor overall HRQOL after adjustment for covariates. In addition, adults with ≥21% HGS asymmetry had 3.29 (95%CI: 1.37–7.91) greater odds for poor mobility.

Conclusions: These findings may be important for clinical screening and population health surveillance. We recommend that HGS asymmetry be included as a standard part of clinical practice and continue to be used in national health surveillance systems.

Keywords: Hand grip strength, Grip strength, Hand grip asymmetry, Health related quality of life (HRQOL), Quality of life (QOL), Well-being, Health Utility Index (HUI), Canadian, Canada

1. Introduction

Health related quality of life (HRQOL) is a broad multidimensional concept that includes subjective evaluations. Even though there is no universal definition of HRQOL, the CDC defines it as an individual's or group's perceived physical and mental health over time (CDC, 2021). HRQOL can bridge boundaries between disciplines (CDC, 2021), and provide insight into adverse health events because it is associated with physical health and physical functioning in adults (Fusco et al., 2012). For example, HRQOL is a significant predictor of mortality in later life (Brown et al., 2015).

One way to measure HRQOL is through self-rated health questionnaires. Strine and colleagues conducted a cross-sectional study to analyze HRQOL, chronic illness, and adverse health behaviors among community dwelling adults and found that HRQOL and health risk behaviors varied with the level of life satisfaction (Strine et al., 2008). Strine and colleagues found that more than one in every 20 U.S. adults (about 12 million) reported that they were dissatisfied or very dissatisfied with their lives. A higher prevalence of young and middle-aged adults are dissatisfied with their lives compared to older adults, with life dissatisfaction associated with obesity and adverse health behaviors such as smoking, heavy drinking, and physical inactivity (Strine et al., 2008). Global self-rated health is also a strong predictor of both health care utilization and mortality among older adults (Dominick et al., 2002). Dominick and colleagues found older adults? reporting very good, good, fair, or poor self-rated health (SRH) had a greater relative risk of 1-month hospitalization than those reporting excellent SRH (Dominick, et al., 2002). DeSalvo and colleagues found significant relationships between poor

SRH and an increased risk of mortality (DeSalvo et al., 2006). Self-rated health is easy to use and can help measure HRQOL over long periods of time.

Muscular strength is commonly measured by handgrip strength (HGS) — a maximal isometric gripping task. It is affordable, quick to administer, requires little testing expertise, and results can be easily scored and interpreted. HGS measured using handheld dynamometry is reliable, valid, and safe (Bellace et al., 2000). Soysal and colleagues conducted an umbrella review of systematic reviews with meta-analyses of observational studies. They found that low HGS was associated with early all-cause mortality, early cardiovascular mortality, physical disability, and low leg power (Soysal et al., 2021). HGS is a widely used measure of muscular strength and is part of long-standing population health surveillance systems such as the Canadian Health Measure Surveys (CHMS) (Statistics Canada, 2013).

The examination of adult HGS asymmetry, also assessed using handheld dynamometry, may help improve assessments of strength capacity and predict future health outcomes (McGrath et al., 2021b). A longitudinal study found that HGS asymmetry may factor into elevated functional disability risk (McGrath et al., 2020). Collins and colleagues found both weakness and HGS asymmetry were differentially associated with functional limitations among older adult Americans (Collins et al., 2020). This indicates that HGS asymmetry, in addition to HGS, may improve the ability to detect functional declines (Collins et al., 2020). Further evaluating HGS asymmetry may improve the prognostic value of handheld dynamometers and improve our understanding of underlying pathways of age-related motor changes to improve screening for age-related disability (McGrath et al., 2021a).

While HGS asymmetry is associated with early all-cause mortality (McGrath et al., 2020), multimorbidity (Klawitter et al., 2021), and functional disability/limitations (McGrath et al., 2020; Collins et al., 2020), no studies to our knowledge have examined HGS asymmetry and HRQOL using nationally-representative Canadian data. The aim of this study, therefore, was to examine the association between HGS asymmetry and HRQOL in a nationally-representative sample of Canadian adults. It was predicted that greater HGS asymmetry was associated with poorer HRQOL.

2. Methods

2.1 Participants

This was a secondary analysis of cross-sectional data from cycles 5 and 6 (2016–2019) of the CHMS dataset. The CHMS is a continuous, nationally-representative dataset on the health and wellness of Canadians aged 3 to 79 years (Statistics Canada, 2012). The CHMS is a voluntary survey conducted by Statistics Canada in partnership with Health Canada and the Public Health Agency of Canada (Day et al., 2007). Approximately 96% of Canadians are represented in the CHMS (Phillips et al., 2020), with individuals living in three territories, on indigenous reserves, or other indigenous settlements, full-time members of the Canadian Forces, institutionalized individuals, or those living in remote regions excluded.

The CHMS was conducted in two steps. Step 1 involved a household interview where demographic and self-reported health information are provided. Step 2 involved direct measures collected by trained staff during an in-person visit set at a scheduled time during the morning or afternoon at a mobile examination center (Canadian Health Measures Survey, 2021). All

participants provided written informed consent. Ethics approval was obtained from the Health Canada and Public Health Agency of Canada research ethics board. Of the initial 11,583 participants, 5673 were excluded because they: (a) were younger than 18 years of age (n=4877), (b) were pregnant (n=44), or (c) had missing data (n=752). These exclusions resulted in a final sample of 5910 Canadian adults aged 18 to 79 years.

2.2 Measures

2.2.1 HGS/HGS Asymmetry

HGS was measured to the nearest kilogram (kg), twice on each hand while alternating between trials, using a Smedley III handgrip dynamometer (Takei Scientific Instruments, Japan) that was adjusted for hand size (Wong, 2016). Participants were measured while standing with the dynamometer held in line with the forearm away from the body at the level of the thigh. HGS asymmetry was calculated as the ratio between the maximum HGS scores for the strongest and weakest hands.

2.2.2 Heath Utility Index

The HUI is a family of generic preference-based systems for measuring comprehensive health status and HRQOL and has been used in hundreds of clinical and general population studies worldwide (Horsman & Gauld, 2018). This system was designed to provide large numbers of detailed descriptions of comprehensive health states (Horsman et al., 2003). There are four key components that comprise the HUI system: a health-status classification system, a preference-based scoring function, data collection questionnaires, and coding algorithms for deriving HUI variables (Horsman et al., 2003). The CHMS used the HUI3 system — a

questionnaire comprising 15 questions to describe an individual's health status (Costet et al., 1998). These questions were asked during the household interview of the CHMS. HUI measures have strong theoretical foundations, are considered valid and reliable, and are well accepted by patients and professionals (Horsman et al., 2003). The overall HRQOL utility scores have a high degree of predictive validity and are nearly perfectly related to the single-attribute utility scores (ICC=0.91) (Feeny et al., 2002).

The HUI3 defines eight attributes including vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain (Feeny et al., 2002). These attributes have five or six health states, capable of describing 972,000 unique health states. Together they provide descriptive measures of ability or disability for health-state attributes and descriptions of comprehensive health status (Horsman et al., 2003). Preference scores for these health states were obtained from a random sample of Canadians aged 18 years and older, with an overall HRQOL utility score (a multi-attribute score) calculated using the algorithm published by (Feeny et al., 2002). The HUI3 values range from –0.36 to 1.00, with –0.36 indicating the worst possible health state, 0.0 indicating death, and 1.0 indicating perfect health. Construct validity is supported by the frequency distribution of 'excellent' and 'very good' responses to the global health status assessment question paralleling changes in mean overall HU13 utility scores (Furlong et al., 2001). Overall HRQOL utility scores were used as the primary variable, with single-attribute utility scores for cognition, mobility, emotion, and pain used as secondary variables.

2.3 Covariates

Age, sex, ethnicity, smoking status, marital status, education level, general health, and mental health were self-reported (see Supplement 1 for more details). Body mass index (BMI), derived from directly measured body mass and standing height, was also included as a covariate. Standing height was measured to the nearest 0.1 cm using a ProScale M235 digital stadiometer (Accurate Technology Inc., Fletcher, United States). Body mass was measured to the nearest 0.1 kg using a Mettler Toledo CW-90/90X terminal scale (Mettler Toledo Canada, Mississauga, Canada). BMI was calculated as body mass in kilograms divided by height in meters squared (kg/m^2). Measurements were taken during the physical assessment portion of the CHMS.

2.4 Statistical Analysis

SAS (v9.4, SAS Institute, Cary, NC, USA) was used for all analyses. The descriptive characteristics were presented overall and for adults with poor and better HRQOL as frequencies (percentage±95% confidence intervals (CI)). Crude and adjusted logistic regression quantified the associations between HGS asymmetry (<11%, 11–20.99%, ≥21% (reference: asymmetry <11%) and the overall HRQOL utility scores. Poor HRQOL was defined as quintile 1 and better HRQOL was defined as quintiles 2–5 of sex- and age-specific overall HRQOL utility scores (Sayer et al., 2006). The adjusted models included age, sex, race, marital status, education level, BMI, self-reported general health, and self-reported mental health as covariates. Results from the adjusted models were considered as the primary results. Associations between HGS asymmetry and the single-attribute utility scores for mobility, pain, emotion, and cognition were also examined. Bootstrap and sample weights were used for all logistic regression models to account for the complex CHMS design and nonresponse bias (Statistics Canada, 2012).

3. Results

3.1 Sample Description and Characteristics

The descriptive characteristics of the 5910 Canadian adults included in this study are presented in Table 1. Overall, participants were predominantly young adults aged 18–39 years (39.1%), women (50.8%), white (70.7%), married (64.0%), and high school graduates (84.8%). A higher proportion of adults with ≥21%HGS asymmetry had poor HRQOL compared to better HRQOL.

Table 1. Descriptive characteristics of the study participants.

Variable	Overall	Poor HRQOL	Better HRQOL
	% (95%CI)	% (95%CI)	% (95%CI)
Age			
18–39 years	39.1 (38.1–40.0)	39.4 (34.3–44.4)	39.0 (37.5–40.6)
40–59 years	36.8 (36.0–37.6)	40.6 (35.2–46.0)	36.0 (34.5–37.4)
60–79 years	24.1 (23.4–24.8)	20.0 (16.1–23.9)	25.0 (23.9–26.1)
Sex			
Male	49.2 (48.2–50.1)	54.6 (49.5–59.8)	48.0 (46.5–49.5)
Female	50.8 (49.9–51.8)	45.4 (40.2–50.5)	52.0 (50.5–53.5)
Race			
White	70.7 (61.5–79.9)	69.9 (57.8–82.1)	70.8 (62.1–79.6)
Visible minority	29.3 (20.1–38.5)	30.1 (17.9–42.2)	29.2 (20.4–37.9)
Marital status			
Married or common law	64.0 (61.8–66.1)	53.6 (47.7–59.6)	66.2 (63.9–68.5)
Single/divorced/widowed	36.0 (33.9–38.2)	46.4 (40.4–52.3)	33.8 (31.5–36.1)
Education			
Secondary or less	15.2 (13.5–16.9)	21.1 (15.9–26.4)	13.9 (12.1–15.8)
Post-secondary	84.8 (83.1–86.5)	78.9 (73.6–84.1)	86.1 (84.2–87.9)
Smoking Status			
Daily/occasional Smoker	15.5 (13.6–17.4)	24.7 (19.3–30.0)	13.5 (11.5–15.5)
Non-Smoker	84.5 (82.6–86.4)	75.3 (70.0–80.7)	86.5 (84.5–88.5)
BMI			
Under/normal weight	41.3 (37.9–44.8)	36.6 (29.8–43.4)	42.4 (38.9–45.9)
Overweight	34.7 (32.6–36.7)	32.1 (27.0–37.1)	35.2 (32.8–37.6)
Obese	24.0 (20.3–27.7)	31.3 (24.3–38.3)	22.4 (18.8–26.0)

General Health			
Excellent/very good	55.3 (52.1–58.5)	29.9 (24.4–35.3)	60.8 (57.7–63.9)
Good/fair/poor	44.7 (41.5–47.9)	70.1 (64.7–75.6)	39.2 (36.1–42.3)
Mental Health			
Excellent/very good	65.9 (62.8–69.0)	38.9 (31.3–46.5)	71.7 (69.3–74.1)
Good/fair/poor	34.1 (31.0–37.2)	61.1 (53.5–68.7)	28.3 (25.9–30.7)
HUI3 attributes			
Mobility			
No mobility issues	98.3 (97.7–98.9)	91.9 (89.2–94.5)	99.7 (99.4–100.0)
Mobility problems	1.7 (1.1–2.3)	8.1 (5.5–10.8)	
Emotion			
Happy/somewhat happy	96.3 (95.2–97.3)	82.2 (76.8–87.5)	99.3 (98.7–99.9)
Somewhat unhappy/unhappy	3.7 (2.7–4.8)	17.8 (12.5–23.2)	
Cognition			
None/little difficulty	71.4 (68.3–74.4)	37.1 (31.5–42.8)	78.7 (75.9–81.6)
Difficulties	28.6 (25.6–31.7)	62.9 (57.2–68.5)	21.3 (18.4–24.1)
Pain			
No pain	82.4 (80.4–84.5)	37.4 (32.2–42.6)	92.1 (90.7–93.6)
Pain prevents activities	17.6 (15.5–19.6)	62.6 (57.4–67.8)	7.9 (6.4–9.3)
HGS asymmetry			
<11%	61.7 (59.3–64.2)	59.4 (54.1–64.7)	62.2 (59.3–65.1)
11–20.99%	25.6 (23.4–27.9)	21.4 (16.3–26.5)	26.5 (23.9–29.2)
≥21%	12.7 (11.0–14.3)	19.2 (15.0–23.3)	11.3 (9.6–12.9)

Notes: Poor HRQOL was defined as quintile 1 and better HRQOL was defined as quintiles 2–5 of sex- and age-specific overall HUI scores; results are shown as frequency (percentage±95%CIs) where indicated. Visible minority includes Black, Latin American, and other (see Supplement 1).
Abbreviations: HRQOL=Health-related quality of life; BMI=body mass index; CI=confidence interval.

3.2 Odds Ratio of HGS Asymmetry

Table 2 shows the associations between HGS asymmetry and overall HRQOL. The crude analysis indicated that relative to adults with <11% asymmetry, adults with ≥21% HGS asymmetry had 1.78 greater odds for poor HRQOL (95%CI: 1.32–2.42), while the adjusted analysis indicated 1.80 greater odds for poor HRQOL (95%CI: 1.26–2.56). Adults with 11–20.99% HGS asymmetry were not at significantly greater odds for poor HRQOL. Both the crude

and adjusted models indicated that adults with ≥21% HGS asymmetry had 3.96 (95%CI: 1.78–8.83) and 3.29 (95%CI: 1.37–7.91) greater odds for poor mobility, respectively. No significant associations were found from adjusted analyses between any HGS asymmetry and other single-attribute utility scores.

Table 2. Crude and adjusted associations between HGS asymmetry and overall/single-attribute HRQOL utility scores.

		Odds Ratio (95%CI)	
HRQOL utility score	**HGS asymmetry**	**Crude**	**Adjusted**
Overall			
	11–20.99%	0.84 (0.59–1.21)	0.70 (0.47–1.05)
	≥21%	1.78 (1.32–2.42)	1.80 (1.26–2.56)
Single-attribute			
Mobility	11–20.99%	0.94 (0.51–1.72)	0.83 (0.44–1.57)
	≥21%	3.96 (1.78–8.83)	3.29(1.37–7.91)
Emotion	11–20.99%	1.82 (0.88–3.78)	1.41 (0.64–3.08)
	≥21%	1.56 (0.82–2.94)	1.46 (0.65–3.25)
Cognition	11–20.99%	0.99 (0.75–1.30)	0.89 (0.68–1.18)
	≥21%	1.10 (0.80–1.52)	1.05 (0.76–1.45)
Pain	11–20.99%	1.00 (0.70–1.44)	0.86 (0.58–1.26)
	≥21%	1.55 (1.15–2.10)	1.33 (0.94–1.87)

Notes: Adjusted models included age, sex, race, marital status, education level, BMI, self-reported general health, and self-reported mental health as covariates. Reference: asymmetry <11%.
Abbreviations: HRQOL=Health-related quality of life; HGS= Handgrip Strength; CI=confidence interval.

4. Discussion

Using a nationally-representative sample of Canadian adults aged 18–79 years, this study found that adult HGS asymmetry was associated with poor HRQOL and mobility. Specifically, adults with ≥21% HGS asymmetry were at 1.80 and 3.29 greater odds for poor overall HRQOL and poor mobility even after adjustment for covariates. Health care providers should consider

assessing adult HGS asymmetry using handheld dynamometry in routine clinical practice to identify at-risk patients. Adults identified as having ≥21% HGS asymmetry should then be recommended appropriate muscle-strengthening activities to achieve symmetric strength and improve HRQOL.

HGS asymmetry may be linked with poor HRQOL due to poor perceived mobility. Analysis of HRQOL surveillance data could be used to identify adults with relatively poor perceived health and help guide interventions to improve health outcomes (CDC, 2021). Evidence strongly encourages clinicians to routinely assess the muscular strength and physical performance of adults. For muscle strength, experts recommend the use of a handheld dynamometer (Beaudart et al., 2019). HGS should be considered as a "vital sign" useful for the clinical screening of older adults (Studenski et al., 2003). Klawitter and colleagues found that HGS asymmetry and weakness were associated with future accumulating morbidities in Americans (Klawitter et al., 2022). Fagerström and Borglin found that mobility rather than functional ability (ADL) contributes to people's HRQOL (Fagerström & Borglin, 2010). The mobility factor alone has the capacity to pick up changes in both physical and mental HRQOL, but this study found that a combination of factors is needed (Fagerström & Borglin, 2010).

Impaired muscle function precedes deficits in whole-body measures of physical performance, as identified by mobility-related tasks such as gait speed, chair stands, timed get-up-and-go tests. Measures of physical performance are now mostly related to ambulation and transfers (Beaudart et al., 2019). Mobility is the most studied function because of its importance in independent living (Parker & Thorslund, 2007). Impairments in physical performance may be

evident way before disability starts (as defined by inability to perform ADLs), so it allows for detection of vulnerability in the first steps of the disabling cascade (Beaudart et al., 2019). In clinical settings, HGS is the measure of choice for the assessment of overall muscle strength, as it has been shown to be a surrogate for lower extremity muscle strength and is easy to measure (Beaudart et al., 2016; Lauretani et al., 2003; Fried et al., 2001). Our findings of a significant association between HGS asymmetry and poor perceived mobility suggests that HGS asymmetry can help with the clinical screening of disablement risk and be used for appropriate referrals that may decelerate losses in physical functioning.

The mechanistic causes underlying muscle dysfunction and poor physical performance may limit the ability to complete basic self-care tasks such as ADLs, which may be why adults with strength asymmetries perceive their mobility as poor. McGrath and colleagues found Americans with both dominant HGS asymmetry and weakness had 86% increased odds for future ADL disability (McGrath et al., 2021b). Therefore, functional strength assessments in clinical settings are needed. Given that strength asymmetry could be linked to factors associated with decreased longevity and poor physical/cognitive function, examining asymmetry in standardized HGS testing protocols could help improve the operationalization of strength capacity and the sensitivity of HGS testing protocols for identifying adults at increased health risk (McGrath et al., 2020). Assessments of HGS asymmetry also preserve the cost-efficiency and feasibility of HGS because multiple measures of HGS are performed on each hand in most HGS test protocols (McGrath et al., 2021b).

Analysis of objectively measured HGS and HGS asymmetry using the CHMS dataset may help evaluate the muscle strengthening portion of Canada's 24-hour movement guidelines (Canadian Society for Exercise Physiology, 2021), which is usually assessed using self-report measures (e.g., questionnaires). Canada's 24-hour movement guidelines recommend performing muscle strengthening activities using major muscle groups twice a week (Canadian Society for Exercise Physiology, 2021). It is unclear whether there have been trends in the proportion of the Canadian population meeting the muscle strengthening recommendation. Tracking changes in HGS asymmetry alongside other CHMS strength measures (e.g., HGS) may help track changes in adherence to national guidelines. Ongoing surveillance of fitness through the CHMS will be important for monitoring trends, examining relationships between fitness and health, and assessing future interventions designed to improve the fitness of the nation (Tremblay et al, 2010).

Future research should examine intervention studies such as muscle-strengthening interventions aimed at improving bilateral strength asymmetries in adults identified as having ≥21% asymmetric strength. Research on recommendations for clinical practice using the Canadian 24-Hour Movement Guidelines for Adults could be used as a starting point for healthcare providers and their patients who exhibit asymmetric strength. Future longitudinal studies should examine whether HGS asymmetry is associated with HRQOL in later life. The examination of criterion-referenced cut-points for HGS asymmetry associated with other health outcomes using overseas adult populations (including low- and middle-income countries) should be analyzed to confirm findings for North American adults and to help develop universal cut-points. While HGS asymmetry cut-points of 10% and 20% have been proposed, the use of

different cut-off points will affect the relationship between HGS asymmetry and health outcomes (Armstrong and Oldham, 1999).

The strengths of this study included the use of (a) a large, recent, nationally-representative sample of Canadian adults, (b) objective HGS measures, and (c) fully adjusted logistic regression models. Limitations included self-report bias associated with the HRQOL assessments, and the cross-sectional study design which prevented the establishment of causal relationships.

5. Conclusion

This study found that Canadian adults with HGS asymmetry of ≥21% had greater odds for poor HRQOL and mobility. These findings may be important for clinical screening and population health surveillance. Handheld dynamometers are an acceptable and feasible tool to assess bilateral strength asymmetry, which should be included as a standard part of clinical practice and continue to be used in national health surveillance systems. Muscle-strengthening activities are recommended for adults identified as having ≥21% HGS asymmetry to correct functional strength asymmetries and improve HRQOL.

REFERENCES

Armstrong, C.A.; Oldham, J.A. A comparison of dominant and non-dominant hand strengths. J. Hand. Surg. 1999, 24, 421–425.

Beaudart C, McCloskey E, Bruyère O et al (2016). Sarcopenia in daily practice: assessment and management. BMC Geriatr 16:170. https ://doi.org/10.1186/s1287 7-016-0349-4

Beaudart, C., Rolland, Y., Cruz-Jentoft, A. J., Bauer, J. M., Sieber, C., Cooper, C., ... & Fielding, R. A. (2019). Assessment of muscle function and physical performance in daily clinical practice. *Calcified tissue international*, *105*(1), 1-14.

Bellace JV, Healy D, Besser MP, Byron T, Hohman L. (2000). Validity of the Dexter Evaluation System's Jamar dynamometer attachment for assessment of hand grip strength in a normal population. J Hand Ther. 2000 Jan-Mar;13(1):46-51. doi: 10.1016/s0894-1130(00)80052-6. PMID: 10718222.

Brown, D., Thompson, W., Zack, M., Arnold, S., & Barile, J. (2015). Associations Between Health-Related Quality of Life and Mortality in Older Adults. *Prevention Science*, *16*(1).

Canadian Health Measures Survey (CHMS*)*. Government of Canada, Statistics Canada. (2021, January 7). Retrieved September 21, 2021, from https://www.statcan.gc.ca/eng/survey/household/5071.

Canadian Society for Exercise Physiology (CSEP). (2021). *Canadian 24-Hour Movement Guidelines for Adults aged 18-64 years*. 24Hour Movement Guidelines. Retrieved April 21, 2022, from https://csepguidelines.ca/guidelines/adults-18-64/

Centers for Disease Control and Prevention. (2021). *Health-related quality of life (HRQOL)*. Centers for Disease Control and Prevention. Retrieved April 24, 2022, from https://www.cdc.gov/hrqol/index.htm

Collins, K., Johnson, N., Klawitter, L., Waldera, R., Stastny, S., Kraemer, W. J., Christensen, B., & McGrath, R. (2020). Handgrip strength asymmetry and weakness are differentially associated with functional limitations in older Americans. *International Journal of Environmental Research and Public Health*, *17*(9). https://doi.org/10.3390/ijerph17093231

Costet, N., Le Galès, C., Buron, C., Kinkor, F., Mesbah, M., Chwalow, J., & Slama, G. (1998). French cross-cultural adaptation of the health utilities indexes Mark 2 (HUI2) and 3 (HUI3) classification systems. In *Quality of Life Research* (Vol. 7, Issue 3, pp. 245–256). https://doi.org/10.1023/A:1008830115246 (Costet, N., 1998)

Day, B., Langlois, R., Tremblay, M., & Knoppers, B. M. (2007). Canadian Health Measures Survey: ethical, legal and social issues. *Health Reports / Statistics Canada, Canadian Centre for Health Information = Rapports Sur La Santé / Statistique Canada, Centre Canadien d'information Sur La Santé*, *18 Suppl*(82), 37–51.

DeSalvo, K. B., Bloser, N., Reynolds, K., He, J., & Muntner, P. (2006). Mortality prediction

with a single general self-rated health question. A meta-analysis. *Journal of general internal medicine*, *21*(3), 267–275. https://doi.org/10.1111/j.1525-1497.2005.00291.x

Dominick, K. L., Ahern, F. M., Gold, C. H., & Heller, D. A. (2002). Relationship of health-related quality of life to health care utilization and mortality among older adults. *Aging clinical and experimental research*, *14*(6), 499–508. https://doi.org/10.1007/BF03327351

Fagerström, C., & Borglin, G. (2010). Mobility, functional ability and health-related quality of life among people of 60 years or older. *Aging clinical and experimental research*, *22*(5-6), 387–394. https://doi.org/10.1007/BF03324941

Feeny, D., Furlong, W., Torrance, G. W., Goldsmith, C. H., Zhu, Z., DePauw, S., Denton, M., & Boyle, M. (2002). Multiattribute and single-attribute utility functions for the health utilities index mark 3 system. *Medical care*, *40*(2), 113–128. https://doi.org/10.1097/00005650-200202000-00006

Fried LP, Tangen CM, Walston J et al (2001). Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci 56:M146–M156

Furlong, W. J., Feeny, D. H., Torrance, G. W., & Barr, R. D. (2001). The Health Utilities Index (HUI®) system for assessing health-related quality of life in clinical studies. *Annals of Medicine*, *33*(5), 375–384. https://doi.org/10.3109/07853890109002092

Fusco, O., Ferrini, A., Santoro, M., Lo Monaco, M. R., Gambassi, G., & Cesari, M. (2012). Physical function and perceived quality of life in older persons. Aging Clinical and Experimental Research, 24(1), 68–73. doi:10.1007/BF03325356

Horsman, J., Furlong, W., Feeny, D., & Torrance, G. (2003). The Health Utilities Index (HUI®): Concepts, measurement properties and applications. *Health and Quality of Life Outcomes*, *1*, 1–13. https://doi.org/10.1186/1477-7525-1-54

Horsman, J. R., & Gauld, M. (2018). *Health utilities Inc. "leaders in HEALTH-RELATED quality of Life Research"*. Health Utilities Inc. "Leaders in Health-Related Quality of Life Research". Retrieved September 21, 2021, from http://www.healthutilities.com/. https://doi.org/10.1007/s40520-020-01757-z

Klawitter, L., Bradley, A., Hackney, K. J., Tomkinson, G. R., Christensen, B. K., Kraemer, W. J., & McGrath, R. (2021). The Associations between Asymmetric Handgrip Strength and Chronic Disease Status in American Adults: Results from the National Health and Nutrition Examination Survey. *Journal of Functional Morphology and Kinesiology*, *6*(4), 79.

Klawitter, L., Vincent, B. M., Choi, B. J., Smith, J., Hammer, K. D., Jurivich, D. A., Dahl, L. J., & McGrath, R. (2022). Handgrip Strength Asymmetry and Weakness Are Associated with Future Morbidity Accumulation in Americans. *Journal of Strength and Conditioning Research*, *36*(1), 106–112. https://doi.org/10.1519/JSC.0000000000004166

Lauretani F, Russo CR, Bandinelli S et al (2003). Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. J Appl Physiol 95:1851–1860. https ://doi.org/10.1152/jappl physi ol.00246 .2003

McGrath, R., Clark, B. C., Cesari, M., Johnson, C., & Jurivich, D. A. (2021a). Handgrip strength asymmetry is associated with future falls in older Americans. *Aging Clinical and Experimental Research*, *33*(9), 2461–2469. https://doi.org/10.1007/s40520-020-01757-z

McGrath, R., Tomkinson, G. R., LaRoche, D. P., Vincent, B. M., Bond, C. W., & Hackney, K. J. (2020). Handgrip Strength Asymmetry and Weakness May Accelerate Time to Mortality in Aging Americans. *Journal of the American Medical Directors Association*, *21*(12), 2003-2007.e1. https://doi.org/10.1016/j.jamda.2020.04.030

McGrath, R., Vincent, B. M., Jurivich, D. A., Hackney, K. J., Tomkinson, G. R., Dahl, L. J., & Clark, B. C. (2021b). Handgrip strength asymmetry and weakness together are associated with functional disability in aging americans. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*, *76*(2), 291–296. https://doi.org/10.1093/gerona/glaa100

Parker, M. G., & Thorslund, M. (2007). Health trends in the elderly population: Getting better and getting worse. *Gerontologist*, *47*(2), 150–158.https://doi.org/10.1093/geront/47.2.150

Phillips, E. W., Rao, D. P., Kaminsky, L. A., Tomkinson, G. R., Ross, R., & Lang, J. J. (2020). Criterion-referenced mCAFT cut-points to identify metabolically healthy cardiorespiratory fitness among adults aged 18-69 years: An analysis of the canadian

health measures survey. *Applied Physiology, Nutrition and Metabolism*, *45*(9), 1007–1014. https://doi.org/10.1139/apnm-2019-0874

Sayer, A. A., Syddall, H. E., Martin, H. J., Dennison, E. M., Roberts, H. C., & Cooper, C. (2006). Is grip strength associated with health-related quality of life? Findings from the Hertfordshire Cohort Study. *Age and Ageing*, *35*(4), 409–415. https://doi.org/10.1093/ageing/afl024

Soysal, P., Hurst, C., Demurtas, J., Firth, J., Howden, R., Yang, L., Tully, M. A., Koyanagi, A., Ilie, P. C., López-Sánchez, G. F., Schwingshackl, L., Veronese, N., & Smith, L. (2021). Handgrip strength and health outcomes: Umbrella review of systematic reviews with meta-analyses of observational studies. *Journal of Sport and Health Science*, *10*(3), 290–295. https://doi.org/10.1016/j.jshs.2020.06.009

Statistics Canada: *Muscular strength of Canadians, 2009 to 2011*. (2013). Canada's national statistical agency / Statistique Canada : Organisme statistique national du Canada. (2013, February 11). Retrieved September 21, 2021, from https://www150.statcan.gc.ca/n1/pub/82-625-x/2012001/article/11710-eng.htm#archived.

Statistics Canada. (2012). *Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 2* (Issue September).

Strine, T. W., Chapman, D. P., Balluz, L. S., Moriarty, D. G., & Mokdad, A. H. (2008). The associations between life satisfaction and health-related quality of life, chronic illness, and health behaviors among U.S. community-dwelling adults. *Journal of Community Health*, *33*(1), 40–50. https://doi.org/10.1007/s10900-007-9066-4

Studenski, S., Perera, S., Wallace, D., Chandler, J. M., Duncan, P. W., Rooney, E., ... & Guralnik, J. M. (2003). Physical performance measures in the clinical setting. *Journal of the American Geriatrics Society*, *51*(3), 314-322.

Tremblay, M. S., Shields, M., Laviolette, M., Craig, C. L., Janssen, I., & Gorber, S. C. (2010). Fitness of Canadian children and youth: results from the 2007-2009 Canadian Health Measures Survey. *Health Reports / Statistics Canada, Canadian Centre for Health Information = Rapports Sur La Santé / Statistique Canada, Centre Canadien d'information Sur La Santé*, *21*(1), 7–20.

Wong, S. L. (2016). Reduced muscular strength among Canadians aged 60 to 79: Canadian Health Measures Survey, 2007 to 2013. *Health Reports*, *27*(10), 11–17.

SUPPLEMENT 1

The following self-reported covariates were included:

Age: Age at last birthday ranging from 1 to 85 years. (DHH_AGE)

Sex: Male or female. (DHH_SEX)

Marital status: Single, married, refuse, or don't know. (DHH_MS)

Race: White, Black, Latin American, or Other (Arab, Southeast Asian, West Asian, Korean, Japanese, South Asian, Chinese, Filipino) (PGDCGT)

Smoking status: Do you smoke cigarettes daily, occasionally, or not at all? (SMKDSTY)

Education level: Are you currently attending school, graduated or have you attended post-secondary schooling? (EDUDH04)

Health status: Is your general health and mental health excellent, very good, good, fair, or poor? (GENDHDI, GENDMHI)