Clinician-Prioritized Measures to Use in a Virtual Concussion Assessment: A Delphi Study

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Abstract

Background: There is little guidance available, and no uniform assessment battery used in either in-person and remote evaluations of people who are experiencing persistent symptoms post-concussion. There are, however, a variety of measures available to assess the physical domains affected by concussion and selecting the most appropriate measures for both in-person and virtually is challenging because of the lack of expert consensus and guidance.

Objective: This mixed-methods study used expert consensus processes to: i) identify clinical measures currently used to assess five physical domains affected by concussion (neurological examination, cervical spine, vestibular, oculomotor, effort), ii) document the available psychometric properties of the identified measures, and iii) determine the feasibility of applying the identified measures virtually.

Methods: The Delphi approach was used. In the first round, experienced clinicians were surveyed regarding their use of measures in concussion assessment. In the second round, clinicians reviewed information regarding the psychometric properties for all measures that were identified in the first round by at least 15% of participants. In the second round, experts rank-ordered the measures from most relevant to least relevant based on their clinical experience and the documented psychometric properties. A working group of 4 expert clinicians then determined feasibility to virtually administer the final set of measures.

Results: Fifty-nine clinicians completed survey Round 1 listing all measures they used to assess the physical domains affected by a concussion. The frequency counts of the 146 different measures identified were determined. Thirty-three clinicians then completed the second-round survey and rank-ordered 22 measures that met the 15% cut-off criterion retained from Round 1. Measures ranked first (under the following domains: neurological examination, cervical spine, vestibular, oculomotor) were coordination, range of motion, Vestibular Ocular Motor Screening (VOMS), and smooth pursuits. These measures were deemed feasible to administer virtually by the working group members, however modifications for virtual administration were recommended, such as adjusting the method of measurement. There is limited information available on the psychometric properties of the Round 2 identified measures.

Conclusions: Clinicians ranked assessment of coordination, cervical spine range of motion, VOMS, and smooth pursuits as most relevant under their respective domains. Unfortunately, there are minimal documented psychometric properties for some of the identified measures suggesting the need for further study. Nevertheless, based on expert opinion, these clinical measures are considered feasible to administer for concussion physical examinations in the virtual context, with modifications.

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Abstract

Background: There is little guidance available, and no uniform assessment battery used in either in-person and remote evaluations of people who are experiencing persistent physical symptoms post-concussion. Selecting the most appropriate measures for both in-person and virtual physical assessments is challenging because of the lack of expert consensus and guidance.
Objective: This study used expert consensus processes to: i) identify clinical measures currently used to assess five physical domains affected by concussion (neurological examination, cervical spine, vestibular, oculomotor, effort) and ii) determine the feasibility of applying the identified measures virtually.
Methods: The Delphi approach was used. In the first round, experienced clinicians were surveyed regarding their use of measures in concussion assessment. In the second round, clinicians reviewed information regarding the psychometric properties for all measures that were identified in the first round by at least 15% of participants. In the second round, experts rank-ordered the measures from most relevant to least relevant based on their clinical experience and the documented psychometric properties. A working group of 4 expert clinicians then determined feasibility to virtually administer the final set of measures.
Results: Fifty-nine clinicians completed survey Round 1 listing all measures they used to assess the physical domains affected by a concussion. The frequency counts of the 146 different measures identified were determined. Thirty-three clinicians then completed the second-round survey and rank-ordered 22 measures that met the 15% cut-off criterion retained from Round 1. Measures ranked first were coordination, range of motion, Vestibular Ocular Motor Screening (VOMS), and smooth pursuits. These measures were feasible to administer virtually by the working group members, however modifications for virtual administration were recommended, such as adjusting the method of measurement.
Conclusions: Clinicians ranked assessment of coordination (finger to nose test and rapid alternating movement test), cervical spine range of motion, VOMS, and smooth pursuits as most relevant measures under their respective domains. Based on expert opinion, these clinical measures are considered feasible to administer for concussion physical examinations in the virtual context, with modifications, however the psychometric properties have yet to be explored.

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Clinician-Prioritized Measures to Use in a Virtual Concussion Assessment: A Delphi Study

Introduction

Concussions also known as mild traumatic brain injuries can occur in a variety of different settings such as within sport, in the workplace and from falls that occur during activities of daily living [1]. A diverse group of clinicians including sports medicine physicians, neurologists, physiatrists, and physiotherapists may complete physical assessments post-concussion. Approaches to completing the concussion physical examination appear to be variable amongst clinicians. While the available guidelines provide an overview of the important components of a vocational assessment following a concussion [2], there are no widely agreed upon guidelines outlining specific measures to use in the concussion assessment. This is particularly important in the context of work-related injuries where benefits and treatment are related to clinical findings. Roughly 1 in 5 adults are unable to return to work at 6 months post-injury following their concussion [1], many of whom require specialized assessment at this time point post-injury.

A number of domains, each with a variety of potential measures, should be assessed in the concussion examination [2]. Furthermore, different measures may be used when the injured person is evaluated immediately following a concussion injury, a few days following the injury, and a few months following the injury. Leddy et al. [3] outlined an evidence-based physical examination for neurologists assessing adults presenting with persistent symptoms post-concussion, however, specific measures for certain domains remains undefined.

Identification of appropriate measures for remote concussion assessment is an important challenge that moved to the forefront of healthcare with the COVID-19 driven shift in clinical practice to virtual care. Remote concussion assessments are increasingly common, yet the measures used to complete these assessments continue to vary due to the lack of standardization and consistency regarding best practices amongst clinicians. In response to this shift, virtual examination resources targeting family medicine physicians have been developed to support the diagnosis and acute evaluation of concussion through remote assessment [4]. These resources outline approaches that can be transferred from the typical in-person concussion examination to a virtual context. Specific limitations include orthostatic vitals, dynamic gait, and cardiovascular/respiratory evaluation that are very difficult to complete in a virtual context without special equipment sent to the patient. Also, in response to the shift to virtual care, McPherson et al. [5] published adaptations to the evaluation of cranial nerves, oculomotor, vestibular, and cervical spine deficits along with assessment of orthostatic intolerance from the Buffalo Concussion Physical Examination for use in remote assessment of sport outpatients (in both acute and persistent symptom contexts). Finally, a living guideline for the acute assessment and management of pediatric concussion presents approaches to completing the virtual concussion examination in the pediatric population [6]. These resources are based on expert opinion and support the feasibility of completing components of the concussion examination remotely. Variations in the approaches to remote assessment presented in the above-noted resources highlights the lack of standardized approaches to the virtual assessments currently used in clinical practice. Furthermore, most of these resources were developed in the context of the sport setting or the pediatric patient population. Information is lacking on the measures recommended for use in remote concussion examination of community-dwelling adults who may have sustained a concussion injury in the workplace and are experiencing persistent symptoms.

In the absence of evidence or sufficient information to support clinical decisions, such as decisions on clinical measures to use in practice, expert consensus is often sought [7,8]. One approach to finding consensus on possible clinical measures is to use the Delphi method and typically involves at least two rounds of survey administration to expert clinicians. Commonly, exploratory questions are asked in the first round followed by more targeted, specific questions in a subsequent round. The Delphi method is a useful approach to obtain anonymous opinions from several individuals across disciplines and wide-spread locations [7]. Expert opinions on the topic of interest transform into consensus in this approach [9]. Importantly, consensus does not indicate that the measures selected are the correct measures to use in a concussion assessment. Rather, the results from the consensus act to structure follow-up discussions (in working groups) and inform subsequent decisions [10].

Previous work has used the Delphi approach to identify clinical measures in various populations. Reneker et al. [11] aimed to document the cervical spine measures used in concussion to distinguish between cervicogenic and other factors contributing to dizziness post-sport related concussion. Consensus on clinical utility of the identified measures was determined by the clinicians who participated in the study. Similarly, while not specific to concussion, Winser et al. [12] used a Delphi approach to identify balance measures used by clinicians to evaluate people with cerebellar ataxia. Clinicians were first asked to list the measures that they use in practice and then select the most appropriate measure for the assessment of balance. This study identified three balance measures (Berg Balance Scale, the Scale for the assessment and rating of ataxia, and the Timed Up and Go) as most appropriate, however, noted that evaluation of test psychometric properties is needed. While these studies identify balance and cervical spine measures for specific purposes, there remains limited information on the identification of clinical measures to use in the evaluation of physical domains impacted by a concussion.

The purpose of this work was to: i) identify clinical measures currently used to assess five pre-defined domains following a concussion injury (neurological examination, vestibular, oculomotor, cervical spine, and effort); and ii) determine the feasibility of administering the measures remotely. Findings from this study will inform the selection of measures for use in a virtual concussion assessment that will be tested in a planned evaluative study. We focused on the physical domains of a concussion examination since they appear to be more challenging and require more adaptations to administer virtually when compared to measures of cognitive or emotional health. Further, while there is overlap in concussion symptom domains, classification systems typically segregate physical symptoms from cognitive and emotional symptoms. For example, Ellis et al. [15] presented a classification system in which signs and symptoms post-concussion are grouped into physiologic, vestibulo-ocular, cervicogenic, and cognitive/mood-related domains.

Methods

The complete methodology is presented in Barnes et al. [13]. The published protocol presents a flow diagram of the methodological process, which includes a Round 1 survey to identify clinical measures used to evaluate physical domains impacted by a concussion, a Round 2 survey to rank-order the identified measures from Round 1, and a working group to document the perceived feasibility of administering the identified measures from the surveys in a virtual environment. This study was approved by the Ottawa Health Sciences Network Research Ethics Board (20210575-01H), the Bruyère Research Institute Research Ethics Board (M16-22-006) and the University of Ottawa Board of Ethics (H-02-22-7611).

Delphi Survey Approach

Round 1

An open invitation was sent to clinician-members of 8 regional and 4 national brain injury/concussion and professional associations/networks through email and monthly newsletters over a span of 3 months (February to May 2022). Wherever possible, targeted emails to clinicians with publicly available contact information were employed to ensure there was a representative sample of at least 2 participants from each clinical profession of interest (physiatry, sports medicine, neurology, and physiotherapy). Purposive sampling techniques were employed to recruit at least 50 expert Canadian-practicing clinicians with experience completing in-person concussion assessments in any setting (sport contexts, emergency departments, rehabilitation centers, family medicine offices, etc.). Justification of the sample size is presented in the published protocol [13]. As reported by Hasson [10], inclusion of participants who have an interest in the topic and knowledge about the topic may aid with increasing content validity of the findings of the Delphi approach. Through the open invitation and self-reports of competency, we were able to recruit participants who had an interest in concussion assessment and management and who had sufficient experience completing concussion assessments, potentially strengthening the content validity of the survey findings.

A comprehensive list of clinical measures used to assess five domains of concussion (neurological examination, vestibular, oculomotor, cervical spine, and effort assessment) at all time points post-injury (acute, subacute, persistent) was compiled. An ‘other’ domain was also included in Round 1 of the survey due to the anticipated classification variations between clinicians for certain clinical measures. For example, balance or gait tests were included in the vestibular as well as in the ‘other’ domain by clinicians. An adjusted list of measures was created to group all clinical measures under the pre-determined domains. The adjusted list of measures was rank ordered by frequency. Only measures that reached at least 15% agreement ((number of participants that identified measure ÷ total number of participants) × 100) were included in Round 2. Due to the number of measures anticipated to be identified in the survey, we previously set the 15% criteria so that we could narrow down the most relevant measures in the subsequent round, with relatively good level of agreement amongst clinicians. Further, to ensure representation from each clinical profession, we planned to include any measures reaching at least 60% agreement with a professional group in Round 2. All participants who completed Round 1 were invited to complete Round 2. To ensure the survey responses were anonymous, in line with the Delphi approach, a separate form was created for email input so that we could send the Round 1 participants the Round 2 survey.

Development of Reading Materials (Review of the Literature)

As we were particularly interested in the accuracy with which the tools identified pathology, a literature review of the sensitivity and specificity of retained measures was carried out following Round 1 using the following databases: Pubmed (Ovid), Medline (Ovid), CINAHL, and Google Scholar. Search terms used related to the population of interest (all brain injuries due to limited information in the literature on psychometric properties in concussion), psychometric properties of interest (sensitivity and specificity) and clinical measures of interest (measures presented in Table 2). No date limitations were set. The findings from the review of the literature were used to develop descriptions of the identified measures and their psychometric properties; this information was provided in written form to all Round 2 participants. The measures’ sensitivity and specificity metrics identified from the review of the literature that were used to develop the reading materials provided to Round 2 participants is presented in Multimedia Appendix 1.

Round 2

The expert-clinicians were provided with the results of Round 1 and reading materials prior to completing the second-round surveys and were given a month to complete the second survey. Round 1 results were summarized in tables outlining all measures that were at or above the 15% level of agreement and all additional measures that did not meet the cut-off. The sensitivity, specificity and additional considerations for the administration of each measure (e.g. equipment needed, time for administration) identified in the review of literature were presented. The clinicians were then asked to re-rank the identified measures from most to least relevant to their in-person clinical practice. Mean rankings were calculated by summing the product of the weight and frequency count for each measure and dividing by the total number of responses. The weight was determined by the number of measures within each domain.

Working Group

A working group, consisting of a physiatrist, neurologist, physiotherapist-researcher, and sports medicine physician, met in June 2022 to determine feasibility of administering the measures virtually. The working group members were recruited through targeted emails. A moderator (KB) facilitated the working group. The group was audio and video recorded, transcribed into written format and analyzed using content analysis. A physiatrist (MB) (member of the working group but did not attend working group discussion) reviewed the measures independently and commented on feasibility of virtual application of the measures based on personal experience and expertise.

Results

Round 1

Figure 1 presents a flow diagram of the survey process. Fifty-nine clinicians participated in Round 1 of the Delphi survey. The demographic information of the included participants is presented in Table 1. The majority of participants were physiotherapists followed by sports medicine physicians, physiatrists, and neurologists. The ‘other’ category of clinical professions included five occupational therapists, three kinesiologists/athletic therapists, two speech language pathologists, two trainees (medical and physiotherapy), a physician’s assistant, an orthopaedic surgeon, and a family medicine physician. The majority of participants had over 10 years of experience in clinical practice and assessed over 50 people with concussions annually. One participant self-reported ‘strongly incompetent’ for their competency of completing the in-person concussion assessment and therefore their responses were excluded from data analysis as the aim was to survey experts leaving n=58 in Round 1.

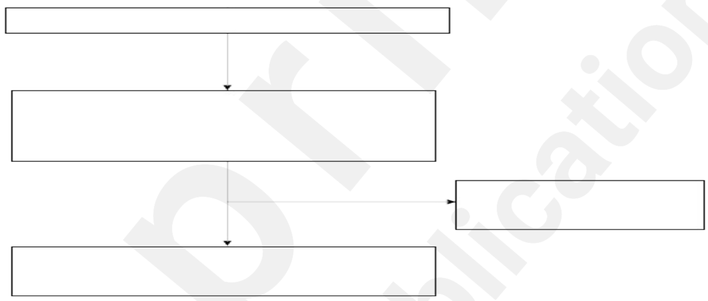

Figure 1. Delphi survey flow diagram.

Table 1: Demographic information of clinicians that completed round 1 survey. N=58

		Frequency	Percentage (%)
Age	20-29	10	17.2
	30-39	25	43.1
	40-49	8	13.8
	50-59	10	17.2
	60+	5	8.6
	Prefer Not to Respond	0	0.0
Clinical Profession	Physiatrist	5	8.6

	Neurologist	2	3.4
	Sports Medicine Physician	10	17.2
	Physiotherapist	26	44.8
	Other	15	25.9
Years in Clinical Practice	1-5	17	29.3
	5-10	13	22.4
	10+	27	46.6
	Did not respond	1	1.7
Volume of Practice (concussion patients assessed per year)	0-25	20	34.5
	25-50	16	27.6
	50+	22	37.9
Self-Report Competency In-Person	Strongly Incompetent	0	0.0
	Incompetent	0	0.0
	Neutral	10	17.2
	Competent	31	53.4
	Strongly Competent	17	29.3
Self-Report Competency Virtual	Strongly Incompetent	2	3.4
	Incompetent	6	10.3
	Neutral	24	41.4
	Competent	23	39.7
	Strongly Competent	3	5.2

After categorizing the measures identified in Round 1 based on the definitions of the domains, 146 different measures were identified (31 measures were identified in the neurological examination domain, 41 were identified in the vestibular domain, 26 in the oculomotor domain, 37 in the cervical spine domain, and 11 in the effort domain). The measures that reached the pre-defined cut-off level of agreement (at least 15%) are presented in Table 2. The list of clinical measures that did not meet the 15% cut-off is presented in Multimedia Appendix 2. The majority of clinicians reported not using any measures to evaluate effort/malingering/symptom validity in their clinical practice. No relevant measures met the cut-off criteria for the effort domain, and it was, therefore, not included in the second survey. Further, when responses were grouped and analyzed based on the clinical profession (physiotherapist, neurologist, physiatrist, sports medicine physician) of the respondents, no additional measures met the criteria of at least 60%.

Table 2: Round 1: List of measures that reached at least 15% agreement. (N=58)

Domain	Measures	Frequency	Agreement (N/58*100)

Neurological Examination	Coordination: finger-to-nose, heel-to-shin; Rapid alternating movements	37	64%
	Cranial nerve	34	59%
	Sensation	20	34%
	Reflexes	19	33%
	Motor (tone, pronator drift, strength/power using MRC grading/MMT)	16	28%
	Myotomes	13	22%
Vestibular	VOMS	25	43%
	Balance (feet together, single leg stance, tandem stance)	23	39%
	VOR assessment	21	36%
	BESS/mBESS	21	36%
	Dix-Hallpike	20	34%
	Head thrust/Head impulse test	14	24%
	Gait/Tandem gait	13	22%
	Romberg	12	20%
	Dynamic Visual Acuity	10	17%
Oculomotor	Saccades	21	36%
	Convergence	20	34%
	Smooth pursuits	15	26%
Cervical	Range of motion	49	84%
	Palpation	26	44%
	Strength (MMT, DNF endurance)	21	36%
	Joint position error test	9	16%

BESS = balance error scoring system; DNF = deep neck flexor; mBESS = modified balance error scoring system; MMT=manual muscle testing; MRC = medical research council; TBI = traumatic brain injury; VOMS = vestibular ocular motor screening; VOR = vestibulo-ocular reflex

Round 2

Thirty-three of the 40 clinicians who agreed to be contacted for Round 2 completed this survey. Table 3 presents the mean rankings for each of the measures and presents the final rank-orders for each of the domains. Multimedia Appendix 3 includes all ranking values, weights and frequency counts.

Table 3: Round 2: Mean rankings of measures.

Domain	Measures	Mean Ranking
Neurological Examination (Mean ranking /6)	Coordination: finger-to-nose, heel-to-shin; Rapid alternating movements	4.67
	Cranial nerve (evaluation of 12 cranial nerves)	4.52
	Motor (tone, pronator drift, strength/power using MRC grading/MMT)	4.09
	Reflexes	2.85
	Myotomes	2.45
	Sensation	2.42
Vestibular (Mean ranking /9)	VOMS	7.52
	Balance (feet together, single leg stance, tandem stance)	6.45

	VOR test	6.18
	BESS/mBESS	5.61
	Dix-Hallpike	4.58
	Gait/Tandem gait	4.36
	Head thrust/Head impulse test	3.91
	Dynamic Visual Acuity	3.52
	Romberg	2.88
Oculomotor (Mean ranking /3)	Smooth pursuits	2.24
	Saccades	1.91
	Convergence	1.85
Cervical (Mean ranking /4)	Range of motion	3.67
	Palpation	2.94
	Strength (MMT, DNF endurance)	1.88
	Joint position error test	1.52

BESS = balance error scoring system; DNF = deep neck flexor; MMT=manual muscle testing; MRC = medical research council; VOMS = vestibula ocular motor screening; VOR = vestibulo-ocular reflex

Working Group

All participants in the working group had over 10 years of experience in clinical practice and self-reported as “competent” or “strongly competent” in completing in-person concussion assessments. Only one working group participant self-reported a neutral competency in completing the virtual assessment, however, all participants had sufficient experience with conducting virtual concussion assessments. All others self-reporting as “competent” or “strongly competent”. Reports of competency were subjective and based on self-perception.

When asked what technologies were used to complete remote assessments, participants reported using either a laptop, desktop, or laptop with large external monitor. Three participants reported not always being able to see the whole body of the patients and only one participant reported being able to see the whole body of patients when completing assessments when requested. The physiatrist who reviewed the measures independently identified similar concerns to those of the members of the working group.

Sixteen measures were deemed feasible to complete virtually but of these, the majority would require modifications (see Table 4). Six measures were deemed infeasible to complete virtually.

Table 4: Working group: Feasibility of completing identified measures virtually as reported by the working group members.

Domain	Measures	Considerations of administering measure virtually as identified by experts	Feasible when administered virtually?

Neurological Examination	Coordination: finger-to-nose, heel-to-shin; Rapid alternating movements	Need to see end point (stable end point) for finger-to-nose: touch camera on screen Heel-to-shin is much more challenging due to positioning of camera: possible if someone is holding the camera Rapid alternating movements is feasible	Y
	Cranial nerve	Taste and smell are a challenge (would see object before smelling) Use of Snellen chart is a challenge Consistency of instructions for administration is a barrier	Y (for majority)
	Motor (tone, pronator drift, strength/power using MRC grading/MMT)	Tone is not feasible Pronator drift is feasible Manual muscle testing is feasible up to 3/5 Cannot complete traditional power testing of muscles Feasible if incorporate a functional test (squat) to provide insight into strength	Y (for majority)
	Reflexes	Only feasible if a trained clinician is with the person in-person	N
	Myotomes	Feasible up to 3/5 grading	Y, but not recommended
	Sensation	Could self-assess but may not be useful information Risk of false negative is high: not recommended virtually	Y with modifications, but not recommended
Vestibular	VOMS	Smooth pursuits, saccades, VOR: feasible (most clinicians only complete these 3 components); need well placed camera VOR: feasible, however keeping at right speed is a challenge; could use metronome smartphone application Convergence: feasible, measurement is the barrier (unless have person helping in-person) Visual motion sensitivity: feasible, however safety concern if standing, need to have enough range (cannot do this in seated position unless have a swivel chair) If solely using VOMS to capture subjective changes in symptoms, then would be feasible	Y with modifications
	Balance (feet together, single leg stance, tandem stance)	Challenge is getting full view of person completing the test Concerns regarding safety, especially with single leg stance Modify environment: have table in front to grab on to, couch nearby to fall into, another person in-person	Y
	VOR test	Challenge is seeing eye movements Feasible if evaluating subjective response	Y
	BESS/mBESS	Full BESS would not be feasible due to safety concerns when standing on foam surface mBESS may be feasible, however safety is still a concern Seeing errors may be a challenge depending on camera angle	Y (mBESS only)
	Dix-Hallpike	Not feasible unless someone trained is with the person in-person	N
	Head thrust/Head impulse test	Not feasible as movement must be unexpected Neck pain is a barrier even in-person	N
	Gait/Tandem gait	Feasible, however safety is a concern Modify environment (couch or wall nearby) or have another person in-person Camera angle is a challenge: prefer profile view when observing gait	Y
	Dynamic Visual Acuity	The computerized dynamic visual acuity test may be feasible, however, need specialized equipment on head, likely making it infeasible Clinical dynamic visual acuity requires a specific set-up (Snellen chart, specific distance from chart), identifying objective difference would be a challenge and therefore likely not feasible Requires a person in-person	N
	Romberg	Feasible, however, safety is a concern and may not be sensitive to balance deficits, especially if administered	Y

		virtually	
Oculomotor	Smooth pursuits	Feasible, person follows finger on screen, could use YouTube videos with object moving to standardize	Y
	Convergence	Feasible, however, measurement is a challenge	Y with modifications
	Saccades	Feasible, look at top corner of one side of screen to top corner of other side	Y
Cervical	Range of motion	Only feasible for active range of motion Feasible, side view for neck flexion and extension, anterior view for lateral flexion, rotation is a challenge (could use smartphone application to detect angle for rotation) Challenge is not being able to complete passive evaluation	Y with modifications
	Palpation	Feasible if self-palpate Subjective but useful information	Y with modifications
	Strength (MMT, DNF endurance)	DNF endurance: not feasible (camera angle would be a challenge, person needs a specific positioning of the neck which would be a challenge to obtain virtually, usually need a hard surface) MMT: Can get an idea of up to 3/5 grading, could complete self-resistance May not be useful for concussion	N
	Joint position error test	Not feasible, specialized equipment and specific positioning needed Could use a modified version where the person looks at the light on the computer and clinician monitors for re-positioning of head May not be generalizable or useful as a screening assessment	N

BESS = balance error scoring system; DNF = deep neck flexor; MMT=manual muscle testing; MRC = medical research council; N = no, measure is not feasible when administered virtually; VOMS = vestibula ocular motor screening; VOR = vestibulo-ocular reflex; Y = yes, measure is feasible when administered virtually

A discussion regarding the sensitivity and specificity of the balance measures occurred during the working group deliberations. Specifically, some clinicians reported that based on their experience with in-person administration, virtual administration of certain measures, such as coordination assessments, provided less reliable information. The Balance Error Scoring System (BESS)/modified BESS (mBESS) was judged by them to have poor ability to distinguish between healthy individuals and individuals with concussion. The working group participants, however, reported that the mBESS and Romberg may be useful tools to screen for gross motor balance deficits in a virtual examination. These measures were, therefore, deemed feasible and potentially useful to include in the virtual concussion assessment for people presenting with persistent symptoms. Based on the Round 2 survey results, balance testing (single leg stance, tandem stance, feet together) and VOMS may be more relevant to clinical practice and therefore more suitable to include in the virtual assessment toolkit. Similarly, the clinicians reported that the objective measurement of convergence in the convergence oculomotor measure and the near point convergence component of the VOMS are extremely challenging to assess in a virtual context, however it could be a useful tool if solely using the test as a screening tool to document subjective changes in symptoms. Some clinicians reported that the amount of reliable information that they receive with virtual administration of the VOMS is minimal, however, components of the test may be useful.

Discussion

In this study we used a Delphi survey methodology to identify all clinical measures clinicians are using to evaluate the physical domains impacted by a concussion injury at all time points post-injury. This was followed by an expert-clinician working group that documented the current perceived feasibility and use of the measures for virtual assessments.

This study confirmed that clinicians use varied approaches when completing in-person evaluations of the physical domains impacted by a concussion injury with almost 150 different concussion evaluation measures identified by the survey clinician-participants. Based on the findings, it appears that there is no widely accepted, standardized approach to assessing concussions, however the use of coordination testing, the VOMS, smooth pursuits, and cervical spine range of motion may be the most relevant measures. This is therefore an area prime for some standardization work. Matuszak et al. [16] documented that the concussion examination in still-symptomatic individuals has not yet been standardized or supported by evidence, and the variation in measures identified in the study may reflect this lack of standardization. According to the Living Concussion Guidelines, valid, standardized tools are needed to assess and monitor symptoms [17], however specific measures containing these characteristics have not yet been outlined. Concussions are a unique condition in which assessments are conducted in a variety of different locations and by a heterogenous group of clinicians [18]. This, therefore, may have contributed to the variety of measures identified by the clinicians that participated in the survey. Further, many factors may have contributed to the selection of measures by the clinician-participants such as time since injury, clinician practice type, cost of clinical measures, equipment needed, ease of use, time needed to administer a measure, accessibility and familiarity, among others [19, 20].

It is possible that the reading material provided to the participants outlining the psychometric properties of the tools based on the review of the literature, did not influence the responses and rankings in the second-round survey resulting in a maintenance in ranking of measures from Round 1 to Round 2. Presenting the reading material, which included information about the measure properties, may have reinforced the participants' original opinions about the clinical measures, leading clinicians to rank the most common measures from Round 1 as first in Round 2. Reasoning for this may be due to the psychometric properties associated with the measures. As demonstrated in Multimedia Appendix 1, the documented psychometric properties are commonly weak to moderate or undefined for many of the measures used in a concussion assessment whether done virtually or in person. Clinician rankings for coordination testing, VOMS and cervical range of motion in Round 1 and Round 2 (within their respective domains) did not change, where all three measures were found to have acceptable sensitivity properties (above 70%), however, the properties available for coordination testing and cervical range of motion are not specific to concussion. Stokes and O'Neill [21] documented that physiotherapists are aware of how to administer clinical measures and track progress using the measures; however, their confidence is lower in terms of their knowledge regarding the properties of the measures. Wedge et al. [22] similarly reported that physiotherapists need more information on the psychometric properties of clinical measures. Most physiotherapists included in the study by Wedge et al. [22] indicated that they did not critically assess the properties of the clinical measures they use in their practice, however there is a desire to have this information more readily available. Many of the physiotherapists further reported that they were unaware of publications providing relevant psychometric property information [22]. Awareness and knowledge of the relevant psychometric properties may therefore inform selection of clinical measures. In practice, clinicians are encouraged to adopt an approach to assessment that is evidence-based, which includes consideration of the current research, clinical expertise, and client or patient preference [23].

There are, however, challenges and barriers to implementing evidence-based practice in clinical settings, such as time limitations, and lack of access to up-to-date research [23]. These factors may have further influenced clinician-selection of measures in the surveys in this study. Clinicians selecting measures without the information provided in this study may have come to different, less evidence-based ranking decisions.

The measures identified in the surveys and discussed in the working group are in line with the recommendations presented in concussion assessment and management guidelines and remote concussion resources [2-4, 6]. Guidance for the virtual general neurologic examination was presented by Al Hussona et al. [24] and aligns with the findings of the working group in this study. According to this guidance, the majority of the cranial nerve examination can be feasibly completed virtually, including: the motor (muscle bulk, pronator drift, antigravity power, squat), sensory (compare light touch or cold on both index fingers and tops of both of the big toes), coordination (including finger-to-nose, heel-to-shin, and rapid alternating movements), and gait (that includes double leg stance, normal gait and tandem gait) examinations. Similarly, according to Ellis et al. [6], a modified cranial nerve examination (in the concussion context) can be completed virtually and includes evaluation of extraocular movements, smooth pursuits, facial symmetry, facial sensation, and movement of palate and tongue. Motor and coordination evaluation according to this guideline includes pronator drift assessment and rapid alternating hand movements. Some limitations identified by Al Hussona et al. [24] for the virtual examination include the inability to perform a fundoscopy examination, detailed power examination, and neuro-otology manoeuvres such as the Dix-Hallpike. While the guidance by Al Hussona et al. [24] is not specific to the concussion examination, it does support the findings of the working group in this study in relation to the concussion assessment as the concerns and considerations that were brought up by the working group members are similar to those presented in the guidance.

Montes et al. [25] developed a roadmap for remote assessment in neuromuscular disorders, and this roadmap could be used across various conditions, including concussion. According to Montes et al. [25], effective adoption of measures in virtual practice should include identifying measures that are clinically relevant and patient-centered. Further, expert opinion and consensus is needed to identify the feasibility of virtual assessments in various populations and conditions. Measures that could be safely and feasibly administered in virtual environments should be the first point of consideration for adaption to virtual environments. Guided by this work by Montes et al. [25], the findings from this study provide an informed foundation on which to base the virtual concussion assessment. It is important to note that this study identifies the clinician-perceived measures that are most relevant to assessing certain physical domains affected by concussion [3]. By identifying the most relevant measures (and some of their associated psychometric properties) used to evaluate the physical domains impacted by a concussion injury that are feasible virtually, we now have an understanding of the clinician-perceived measures that should be initially explored when commencing to determine measures that should be administered in the different contexts, both in-person and virtually.

Limitations

The majority of participants in the Delphi survey were physiotherapists and there was an uneven distribution of participants based on clinical profession. Physiotherapists' opinion may, therefore, be relatively over-represented in this survey compared to the other clinical professions. To address this, we included a cut-off of consensus amongst each clinical profession as well as amongst all participants, however, with only two neurologist, two speech language pathologist, and three kinesiologist/athletic therapist responses, reaching that cut-off would be a challenge for those professions. Similarly, while the working group included representation from clinical professions that typically complete a concussion examination, input may be missing from other clinical professions such as athletic therapists/trainers or kinesiologists, nurses and neurosurgeons. Furthermore, concussion injuries may occur in different contexts and may be assessed by different clinician professionals and at different time points; these factors may contribute to the low level of consensus and broad range of measures identified in both rounds of surveys in our study. There may have been greater consensus if the questions were specific to assessments conducted on people experiencing persistent symptoms post-injury, however, based on the lack of guidance available on the specific measures to use in the assessment of people experiencing persistent symptoms, variation would be expected.

Conclusion

The Delphi approach resulted in low to moderate agreement amongst the clinician-participants regarding the most relevant measures used to evaluate certain physical domains impacted by a concussion injury. This work highlights the broad range of measures being used in practice, however points to the use of coordination testing, the VOMS, smooth pursuits, and cervical spine range of motion as measures that may be most relevant in a concussion examination, within their respective domains. These measures ranked first amongst the survey clinician-participants were determined to be feasible with modifications in a virtual context as decided upon by expert clinicians in the working group. While these measures have been included in most of the remote concussion assessment guidelines and resources, the psychometric properties are underdeveloped for all in the concussion context. These measures, therefore, present a clear starting point for investigation of psychometric properties associated with virtual administration given their rankings and perceived feasibility in the virtual environment.

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Data Availability

All data generated or analyzed during this study are included in this published article.

Authors' Contributions

All authors have made substantial contribution to the work presented in this paper.

Conflicts of Interest

None declared.

Abbreviations

BESS: balance error scoring system

DNF: deep neck flexor

mBESS: modified balance error scoring system

MMT: manual muscle testing

MRC: medical research council

mTBI: mild traumatic brain injury

TBI: traumatic brain injury

VOMS: vestibular/ocular motor screening

VOR: vestibular ocular reflex

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Multimedia Appendix 1

Table S1. List of measures with identified psychometrics that reached at least 15% agreement in round 1. (N=58)

Domain	Measures	Diagnostic Accuracy
Neurological Examination	Coordination: finger-to-nose, heel-to-shin; Rapid alternating movements	Adults with stroke: Timed Finger to nose: **Sensitivity:** 71% **Specificity:** 69% [1]
	Cranial nerve	Adults with focal cerebral hemisphere lesions: Visual field defect: **Sensitivity**: 22% **Specificity**: 95% [2]
	Sensation	Not reported
	Reflexes	Adults with focal cerebral hemisphere lesions: Hyperreflexia: **Sensitivity**: 11% **Specificity**: 100% [2]
	Motor (tone, pronator drift, strength/power using MRC grading/MMT)	Adults with focal cerebral hemisphere lesions: Pronator drift: **Sensitivity:** 22% **Specificity:** 100% Focal muscle weakness: **Sensitivity**: 20-30% **Specificity:** 100% [2]
	Myotomes	Not reported
Vestibular	VOMS	Adults with acute/subacute concussion: **Sensitivity:** 96% **Specificity:** 46% [3]
	Balance (feet together, single leg stance, tandem stance)	Community-dwelling older adults with recurrent falls: Single leg stance: **Sensitivity:** 33% **Specificity:** 71% [4]
	VOR assessment	Not reported
	BESS/mBESS	Adults with acute concussion: **Sensitivity:** 10-60% **Specificity:** 40-93% [5, 6]
	Dix-Hallpike	Adults with benign paroxysmal positional vertigo: **Sensitivity:** 82% **Specificity:** 71% [7]
	Head thrust/Head impulse test	Adults with vestibular hypofunction: **Sensitivity:** 63-72% **Specificity:** 64-78% [8]
	Gait/Tandem gait	Youth with acute/subacute concussion: Tandem gait: **Sensitivity:** 41% **Specificity**: 90% [9]

	Romberg	Young adults with vestibular dysfunction: **Sensitivity:** 55% **Specificity:** 64% [10]
	Dynamic Visual Acuity	Not reported
Oculomotor	Saccades	Youth and adults with TBI: Computerized only: Horizontal: **Sensitivity:** 77% **Specificity:** 78% Vertical: **Sensitivity:** 64% **Specificity:** 65% [11]
	Convergence	Not reported
	Smooth pursuits	Youth and adults with TBI: Computerized only: **Sensitivity**: 68% **Specificity:** 73% [12]
Cervical	Range of motion	Adults with whiplash: Computerized: **Sensitivity:** 86%, **Specificity:** 95% [13]
	Palpation	Not reported
	Strength (MMT, DNF endurance)	Not reported
	Joint position error test	Adults with cervical spine injury: **Sensitivity:** 82% **Specificity:** 90% [14]

BESS = balance error scoring system; DNF = deep neck flexor; mBESS = modified balance error scoring system; MMT=manual muscle testing; MRC = medical research council; TBI = traumatic brain injury; VOMS = vestibular ocular motor screening; VOR = vestibulo-ocular reflex

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Multimedia Appendix 2
Delphi survey round one: measures that did not meet the 15% cut-off criteria

Table S2: Clinician-identified measures that did not meet the 15% cut-off criteria in Delphi survey round one. N=58

Domain	Measures	Frequency	Agreement (N/58*100)
Neurological Examination	Functional testing/capacity	5	9%
	Babinski, Hoffman's	4	7%
	Infrared Goggle Testing	3	5%
	Observation, Auditory screen, Dysmetria, Dysdiaokokinesia, Clonus, Upper limb tension tests, Mental capacity/status	2	3%
	Adiadokokinesis, Calibrated stick drop reaction time, Fukuda step test, Upper motor neuron testing, Hyperventilation, Verbal screen, Plantar reflex, Optic nerve/disc assessment, Cognition, Temporomandibular joint range of motion, Mini-mental state examination, Higher cortical functions, Tremor, Bradykinesia	1	2%
Vestibular	Dynamic gait index	7	12%
	Dizziness handicap inventory	6	10%
	Benign paroxysmal positional vertigo assessment, Head roll test	5	9%
	Functional gait assessment	4	7%
	Motion sensitivity testing, Motion sensitivity quotient, Modified clinical test of sensory interaction in balance (mCTSIB)	3	5%
	Head shake, Mini balance evaluation systems test (MiniBest), Berg, Dynamic balance, Walking on heels, Walking on toes	2	3%
	Otoscopy, Community balance and mobility scale (CB&M), Head impulse nystagmus test of skew examination (HINTS), Gait backwards, Gait sideways, Tandem backwards, Grapevine, Computerized dynamic foot plate, Effects of noise, Pressure (Valsalava, tragal pressure) on symptoms, 10m walk test, modified COBALT, Positional testing (with goggles), Narrow base of support with eyes closed, Epleys, Peripheral vestibular assessment, Visual vertigo analogue score, Provoked vertigo (supine to sit/sit to supine, bend to floor)	1	2%
Oculomotor	Cover eye test/cover/uncover test, Visual fields	8	14%
	Pupil reactivity, Accommodation, Tracking, Nystagmus check	7	12%
	Gaze stabilization	6	10%
	Visual motion sensitivity, Extraocular muscles (EOM)	5	9%
	King-Devick, Visual midline shift	4	7%
	Visual acuity, Fixation	2	3%
	Pupils equal round reactive to light (PERL), Single and 2-point gaze, Optic discs, Diplopia, Focus, Skew deviation, Eyeball movement, Light and accommodations reflex, Subjective visual vertical test, University of Pennsylvania hand out	1	2%
	Vertebral artery assessment	8	14%

Cervical	Spurlings	7	12%
	Proprioception, Flexion rotation test	6	10%
	Alar & transverse ligament tests, Passive intervertebral movements/Passive accessory intervertebral movement (PIVM/PAIVMs), Posture	4	7%
	Tenderness, Deep neck extensor, Joint mobility	3	5%
	Dynamic stability, Smooth pursuit neck torsion test, Cranio-cervical stability	2	3%
	Neck muscle length/tension, Localized pain, Cervical axial compression muscle flexibility, Trigger point assessment, Times testing for neck endurance, Muscle tone and control, Head neck dissociation, Upper limb scan, Dynamic mobility, Head lift endurance, Neck extension rotation test, Joint glides, L'hermitte, RIMS, Upper extremity tests, Muscle bulk activity, Upper extremity strength, Provocative maneuvers for cervicogenic headache, Craniovertebral ligament stability, X-ray cervical spine	1	2%
Effort	None	31	53%
	Buffalo Concussion Treadmill Test	10	17%
	Buffalo Concussion Bike Test, Functional lifting	4	7%
	Observation, Immediate post-concussion assessment and cognitive test (ImPACT), Consistency of presentation/Abnormal responses, Treadmill test	3	5%
	Waddel sign	2	3%
	Rey's 15 item test, Attentional test, RPE, Symptom scales	1	2%

Multimedia Appendix 3
Round Two Mean Rankings

Table S3: Delphi survey round two mean rankings for each measure.

		Mean Rankings		Response Count and Weight																										
				Rank 1			Rank 2			Rank 3			Rank 4			Rank 5			Rank 6			Rank 7			Rank 8			Rank 9		
Domain	Measures	Mean Ranking	Sum of all (weight*response count)	Frequency (#)	Weight	Weight*Response Count	Frequency (#)	Weight	Weight*Response Count	Frequency (#)	Weight	Weight*Response Count	Frequency (#)	Weight	Weight*Response Count	Frequency (#)	Weight	Weight*Response Count	Frequency (#)	Weight	Weight*Response Count	Frequency (#)	Weight	Weight*Response Count	Frequency (#)	Weight	Weight*Response Count	Frequency (#)	Weight	Weight*Response Count
Neurological Examination	Cerebellar testing (Coordination: finger-to-nose, heel-to-shin; Rapid alternating movements)	4.666666667	154	10	6	60	16	5	80	0	4	0	2	3	6	4	2	8	0	1	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Cranial nerve	4.515151515	149	17	6	102	4	5	20	3	4	12	1	3	3	4	2	8	4	1	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Sensation	2.424242424	80	0	6	0	1	5	5	6	4	24	7	3	21	11	2	22	8	1	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Reflexes	2.848484848	94	2	6	12	1	5	5	6	4	24	10	3	30	9	2	18	5	1	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Motor (tone, pronator drift, strength/power using MRC grading/MMT)	4.090909091	135	4	6	24	8	5	40	14	4	56	3	3	9	1	2	2	4	1	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Myotomes	2.454545455	81	0	6	0	3	5	15	4	4	16	10	3	30	4	2	8	12	1	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vestibular	VOMS	7.515151515	248	17	9	153	3	8	24	3	7	21	5	6	30	2	5	10	1	4	4	2	3	6	0	2	0	0	1	0
	Balance (feet together, single leg stance, tandem stance)	6.454545455	213	5	9	45	11	8	88	4	7	28	6	6	36	1	5	5	0	4	0	1	3	3	3	2	6	2	1	2
	VOR test	6.181818182	204	1	9	9	9	8	72	6	7	42	5	6	30	7	5	35	3	4	12	1	3	3	0	2	0	1	1	1
	BESS/mBESS	5.606060606	185	2	9	18	4	8	32	6	7	42	7	6	42	3	5	15	5	4	20	4	3	12	2	2	4	0	1	0
	Dix-Hallpike	4.575757576	151	3	9	27	1	8	8	2	7	14	5	6	30	8	5	40	2	4	8	5	3	15	2	2	4	5	1	5
	Head thrust/Head impulse test	3.909090909	129	2	9	18	1	8	8	5	7	35	1	6	6	3	5	15	4	4	16	5	3	15	4	2	8	8	1	8
	Gait/Tandem gait	4.363636364	144	3	9	27	1	8	8	5	7	35	3	6	18	1	5	5	7	4	28	3	3	9	4	2	8	6	1	6
	Romberg	2.878787879	95	0	9	0	0	8	0	1	7	7	1	6	6	6	5	30	1	4	4	9	3	27	6	2	12	9	1	9
	Dynamic Visual Acuity	3.515151515	116	0	9	0	3	8	24	1	7	7	0	6	0	2	5	10	10	4	40	3	3	9	12	2	24	2	1	2
Oculomotor	Saccades	1.909090909	63	7	3	21	16	2	32	10	1	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Convergence	1.848484848	61	11	3	33	6	2	12	16	1	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Smooth pursuits	2.242424242	74	15	3	45	11	2	22	7	1	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cervical	Range of motion	3.666666667	121	25	4	100	6	3	18	1	2	2	1	1	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Palpation	2.939393939	97	7	4	28	20	3	60	3	2	6	3	1	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Strength (MMT, DNF endurance)	1.878787879	62	0	4	0	2	3	6	25	2	50	6	1	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Joint position error test	1.515151515	50	1	4	4	5	3	15	4	2	8	23	1	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Multimedia Appendix 4
Round Two Consensus Values

While the aim of the study was to identify the most relevant measures using rank-orders of measures, consensus values for rankings of each measure were also calculated. Frequency counts and consensus values (calculated by dividing frequency counts by number of responses for each ranking) for measures that reached or exceeded 50% consensus are shown in table S4. The consensus target, greater than 50%, was reached on the first-ranked measure for three of the five domains. For the neurological examination and vestibular domains, consensus at 51.52% was reached for the first ranked outcome measures of cranial nerve evaluation and VOMS, respectively. The cervical spine assessment was the only domain where consensus was reached for all measures (range of motion, followed by palpation, followed by strength, followed by the joint position error test) with range of motion ranked as most relevant at 75.76%. There was no consensus on the oculomotor domain measures.

Table S4: Frequency counts and consensus values for measures reaching at least 50% consensus within each rank.

		Frequency (#) and Consensus (%)							
		Rank 1		Rank 2		Rank 3		Rank 4	
Domain	Measures	#	%	#	%	#	%	#	%
Neurological Examination	Coordination: finger-to-nose, heel-to-shin; Rapid alternating movements	-	-	-	-	-	-	-	-
	Cranial nerve	17	51.52	-	-	-	-	-	-
	Motor (tone, pronator drift, strength/power using MRC grading/MMT)	-	-	-	-	-	-	-	-
Vestibular	VOMS	17	51.52	-	-	-	-	-	-
Cervical	Range of motion	25	75.76	-	-	-	-	-	-

	Palpation	-	-	20	60.61	-	-	-	-
	Strength (MMT, DNF endurance)	-	-	-	-	25	75.76	-	-
	Joint position error test	-	-	-	-	-	-	23	69.70

MMT=manual muscle testing; MRC = medical research council

Frequency counts and consensus values for all measures that met the previously set criteria (15% of clinicians identifying a measure) are presented in table S5.

Table S5: Delphi survey round two frequency counts and consensus values for all measures that met the previously set criteria

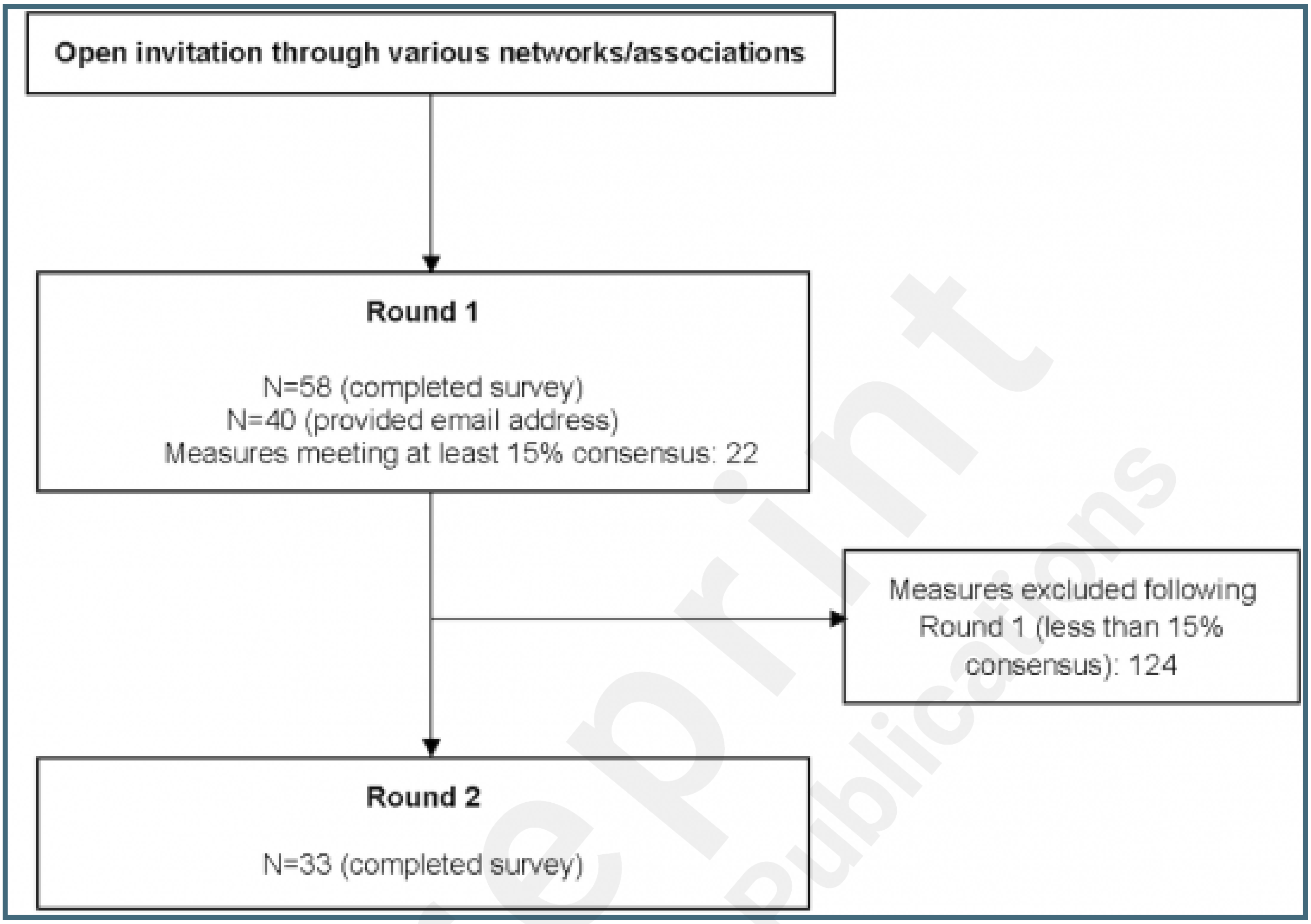
		Frequency (#) and Consensus (%)																	
		Rank 1		Rank 2		Rank 3		Rank 4		Rank 5		Rank 6		Rank 7		Rank 8		Rank 9	
Domain	Measures	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Neurological Examination	Cerebellar testing (Coordination: finger-to-nose, heel-to-shin; Rapid alternating movements)	10	30.30	16	48.48	0	0.00	2	6.06	4	12.12	0	0.00	N/A	N/A	N/A	N/A	N/A	N/A
	Cranial nerve	17	51.52	4	12.12	3	9.09	1	3.03	4	12.12	4	12.12	N/A	N/A	N/A	N/A	N/A	N/A
	Sensation	0	0.00	1	3.03	6	18.18	7	21.21	11	33.33	8	24.24	N/A	N/A	N/A	N/A	N/A	N/A
	Reflexes	2	6.06	1	3.03	6	18.18	10	30.30	9	27.27	5	15.15	N/A	N/A	N/A	N/A	N/A	N/A
	Motor (tone, pronator drift, strength/power using MRC grading/MMT)	4	12.12	8	24.24	14	42.42	3	9.09	1	3.03	4	12.12	N/A	N/A	N/A	N/A	N/A	N/A
	Myotomes	0	0.00	3	9.09	4	12.12	10	30.30	4	12.12	12	36.36	N/A	N/A	N/A	N/A	N/A	N/A
Vestibular	VOMS	17	51.52	3	9.09	3	9.09	5	15.15	2	6.06	1	3.03	2	6.06	0	0.00	0	0.00
	Balance (feet together, single leg stance, tandem stance)	5	15.15	11	33.33	4	12.12	6	18.18	1	3.03	0	0.00	1	3.03	3	9.09	2	6.06
	VOR test	1	3.03	9	27.27	6	18.18	5	15.15	7	21.21	3	9.09	1	3.03	0	0.00	1	3.03
	BESS/mBESS	2	6.06	4	12.12	6	18.18	7	21.21	3	9.09	5	15.15	4	12.12	2	6.06	0	0.00
	Dix-Hallpike	3	9.09	1	3.03	2	6.06	5	15.15	8	24.24	2	6.06	5	15.15	2	6.06	5	15.15
	Head thrust/Head impulse test	2	6.06	1	3.03	5	15.15	1	3.03	3	9.09	4	12.12	5	15.15	4	12.12	8	24.24
	Gait/Tandem gait	3	9.09	1	3.03	5	15.15	3	9.09	1	3.03	7	21.21	3	9.09	4	12.12	6	18.18
	Romberg	0	0.00	0	0.00	1	3.03	1	3.03	6	18.18	1	3.03	9	27.27	6	18.18	9	27.27
	Dynamic Visual Acuity	0	0.00	3	9.09	1	3.03	0	0.00	2	6.06	10	30.30	3	9.09	12	36.36	2	6.06
Oculomotor	Saccades	7	21.21	16	48.48	10	30.30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Convergence	11	33.33	6	18.18	16	48.48	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Smooth pursuits	15	45.45	11	33.33	7	21.21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cervical	Range of motion	25	75.76	6	18.18	1	3.03	1	3.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Palpation	7	21.21	20	60.61	3	9.09	3	9.09	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Strength (MMT, DNF endurance)	0	0.00	2	6.06	25	75.76	6	18.18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Joint position error test	1	3.03	5	15.15	4	12.12	23	69.70	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Supplementary Files

Figures

Delphi survey flow diagram.



Multimedia Appendixes

List of measures with identified psychometrics that reached at least 15% agreement in round 1.
URL: http://asset.jmir.pub/assets/b8335513042e8fb07cdb0f3e4896848e.docx

Delphi survey round one: measures that did not meet the 15% cut-off criteria.
URL: http://asset.jmir.pub/assets/83e8ef293b40b892f2aed9b656f02740.docx

Round two mean rankings.
URL: http://asset.jmir.pub/assets/66daf53d24278e9c9b4b8e9f8dbaee90.docx

Round two consensus values.
URL: http://asset.jmir.pub/assets/bb32580f8704b9380663a0b79857407d.docx