Digital innovations in Assessment of Acquired Brain Injury: A Scoping Review.

Carl O'Brien, Aoife Murray, Gerard McManus, Chantel Debert

Submitted to: Journal of Medical Internet Research
on: March 02, 2025

Table of Contents

Digital innovations in Assessment of Acquired Brain Injury: A Scoping Review.

Carl O'Brien[1, 2] MBBChMBO, MSc, MRCPI; Aoife Murray[3] MBBChMBO, MSc, MRCPI; Gerard McManus[4] BA, MA, GradDipLis; Chantel Debert[5, 6] MD, MSc, FRCPC, CSCN

[1]3330 Hospital Dr NW, University of Calgary Hotchkiss Brain institute Calgary CA
[2]Apt 404, 921 17th Avenue Southwest Royal College of Physicians of Ireland Dublin IE
[3] Royal College of Physicians of Ireland Dublin IE
[4] University College Dublin Dublin IE
[5]3330 Hospital Dr NW University of Calgary Hotchkiss Brain institute Calgary CA
[6] Department of Clinical Neuroscience University of Calgary Calgary CA

Corresponding Author:
Carl O'Brien MBBChMBO, MSc, MRCPI
3330 Hospital Dr NW,
University of Calgary
Hotchkiss Brain institute
626 14th Ave Southwest
Calgary
CA

Abstract

Background: Acquired Brain Injury (ABI) is a leading global cause of morbidity; affecting millions who often suffer from a diverse range of complications and limited access to appropriate care. Advances in digital technology offer promising opportunities for more effective and accessible assessments; however, there is limited comprehensive research on the scope and utilization of these innovations.

Objective: This scoping review aimed to identify and synthesize contemporary research on digital technologies to aid screening or assessment of ABI complications, in order to uncover trends, themes and priorities for future research.

Methods: Using the Arksey and O'Malley framework, a systematic search was conducted across Embase, MEDLINE, and Scopus, with additional searches in four trial registries to capture grey literature. A search string incorporating terms related to "ABI," "clinical assessment," and "digital tools" was developed a priory. Studies from 2013 to 2024 leveraging digital technologies for ABI complication assessment were included. Exclusion criteria comprised studies involving bespoke hardware, non-human subjects or review articles. Data synthesis and domain mapping were performed.

Results: From 5,293 studies extracted, 88 met inclusion criteria: 2 retrospective studies, 4 qualitative studies, 35 cohort studies, 42 cross-sectional studies, and 5 randomized controlled trials. The median sample included 26 participants with ABI, 51 studies also involved non-ABI participants (median of 10 participants included). Most studies (n=70) focused solely on TBI cases, with 36 exclusively on mild TBI or concussion; 16 included mixed ABI etiologies. Digital platforms varied, with 45 studies using smartphone or tablet technologies, 23 PC or web-based platforms, 11 telemedicine solutions, and 9 virtual reality (VR) platforms.
The predominant research themes included: the use of digital technology to aid in screening for TBI, identifying symptoms or functional outcomes; the assessment of cognition and communication; as well as comprehensive consultation. Most tools were well-tolerated, with accuracy often described as comparable to standard assessments. However, the majority of studies had smaller sample sizes, lacked long term outcomes, were limited in the diversity of patients included, and there were few studies assessing digital tools for comprehensive evaluation.

Conclusions: This investigation provides clinicians and researchers with an extensive overview of current research trends, and highlights the need for larger, more rigorous studies to optimize the use of digital technologies in ABI assessment.
Current studies are often small-scale, designed as pilot or feasibility trials, and show variability in their focus, leaving gaps in the assessment of common complications such as pain, seizures, or participation restrictions. Expanding research into underexplored ABI complications, broadening the scope of assessments and including diverse populations will be critical for advancing the

field and improving outcomes for individuals with ABI. Clinical Trial: NA

(JMIR Preprints 02/03/2025:73331)
DOI: https://doi.org/10.2196/preprints.73331

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http
No. Please do not make my accepted manuscript PDF available to anyone.

Original Manuscript

Digital innovations in Assessment of Acquired Brain Injury: A Scoping Review

Authors and affiliation

Carl O'Brien (1,2), Aoife Murray (1), Gerard MacManus (3), Chantel T Debert (2,4).

(1) Royal College of Physicians of Ireland, Dublin, Ireland.

(2) Hotchkiss Brain Institute, University of Calgary, Calgary, Alberta, Canada

(3) University College Dublin, Dublin, Ireland.

(4) Department of Clinical Neuroscience, University of Calgary, Alberta, Canada

Abstract

Background:

Acquired Brain Injury (ABI) is a leading global cause of morbidity; affecting millions who often suffer from a diverse range of complications and limited access to appropriate care. Advances in digital technology offer promising opportunities for more effective and accessible assessments; however, there is limited comprehensive research on the scope and utilization of these innovations.

Objective:

This scoping review aimed to identify and synthesize contemporary research on digital technologies to aid screening or assessment of ABI complications, in order to uncover trends,

themes and priorities for future research.

Methods:

Using the Arksey and O'Malley framework, a systematic search was conducted across Embase, MEDLINE, and Scopus, with additional searches in four trial registries to capture grey literature. A search string incorporating terms related to "ABI," "clinical assessment," and "digital tools" was developed a priory. Studies from 2013 to 2024 leveraging digital technologies for ABI complication assessment were included. Exclusion criteria comprised studies involving bespoke hardware, non-human subjects or review articles. Data synthesis and domain mapping were performed.

Results:

From 5,293 studies extracted, 88 met inclusion criteria: 2 retrospective studies, 4 qualitative studies, 35 cohort studies, 42 cross-sectional studies, and 5 randomized controlled trials. The median sample included 26 participants with ABI, 51 studies also involved non-ABI participants (median of 10 participants included). Most studies (n=70) focused solely on TBI cases, with 36 exclusively on mild TBI or concussion; 16 included mixed ABI etiologies. Digital platforms varied, with 45 studies using smartphone or tablet technologies, 23 PC or web-based platforms, 11 telemedicine solutions, and 9 virtual reality (VR) platforms.

The predominant research themes included: the use of digital technology to aid in screening for TBI, identifying symptoms or functional outcomes; the assessment of cognition and communication; as well as comprehensive consultation. Most tools were well-tolerated, with accuracy often described as comparable to standard assessments. However, the majority of studies had smaller sample sizes, lacked long term outcomes, were limited in the diversity of patients included, and there were few studies assessing digital tools for comprehensive evaluation.

Conclusions:

This investigation provides clinicians and researchers with an extensive overview of current research trends, and highlights the need for larger, more rigorous studies to optimize the use of digital technologies in ABI assessment.

Current studies are often small-scale, designed as pilot or feasibility trials, and show variability in their focus, leaving gaps in the assessment of common complications such as pain, seizures, or participation restrictions. Expanding research into underexplored ABI complications, broadening the scope of assessments and including diverse populations will be critical for advancing the field and improving outcomes for individuals with ABI.

Introduction

Acquired brain injury (ABI), either due to traumatic brain injury (TBI), neoplasm, encephalitis or a myriad of other causes, is a condition with an impact on millions of individuals worldwide (1). In many developed countries there has been a surge in survival rates thanks to advances in acute care and neurosurgery (2). These have not been mirrored by a corresponding enhancement in equitable access to quality care during the subacute and chronic phase post-injury (3,4). Though survival may be improving, the burden of morbidity and disability continues to rise (5). There is a long list of potential complications from ABI including pain, cognitive deficits, psychological distress, mobility, sensory and balance issues (6). Often these issues are hard to screen for and manage in the acute setting (7). Accessing appropriate care, to identify, treat and diagnose the complications of ABI, can feel like an impossible task for individuals and their families (8). Most health authorities lack an overarching strategy to address increasing demands, with limited services in hospital or the community, threatening to overwhelm the service (9,10).

With the advent and acceleration of digital technologies, healthcare professionals caring for

individuals with ABI have an opportunity to use innovative techniques to assess, monitor and manage complications (11) . The proliferation of mobile phone apps and the ubiquity of social media have made the people with ABI and caregivers more connected than ever, even in the most remote environment (12). Health professionals have also seen an enormous, if fragmentary, increase in digital tools in their practice, although most are not specific to ABI care (11). Innovations in virtual reality, augmented reality, wearable technology, and artificial intelligence have the potential to revolutionize the nature and administration of ABI and make it more equitable, effective, and personalized.

Research into digital technology in healthcare has accelerated in recent years, including in the area of ABI assessment, but there is little information on the breadth of research in this space (13). It is vital to map the advances in ABI assessment to inform strategies for overall care, and reduce the burden on patients, families and health services.

Objectives

This study aimed to identify and chart research in the area of ABI assessment and symptom monitoring, to gain a deeper understanding of recent digital innovations in ABI assessment. The primary objective was to describe research in the use of ubiquitous “off the shelf” digital technologies, (e.g. smartphones, tablet computers, websites, VR platforms and telemedicine platforms) to screen for, assess and monitor the complications of ABI in the past decade. The secondary objective was to chart the predominant technologies being studied, the predominant study methodologies, the characteristics of the study participants and how technology use has changed over time.

Methods

A scoping review was designed by implementing the Arksey and O'Malley Framework (13) and Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines for scoping reviews(14). The Arksey and O'Malley framework outlines 5 key steps in developing and carrying out a scoping review: (1) identifying the research question; (2) identifying relevant studies; (3) developing criteria for appropriate study collection; (4) charting the data, (5) collating, summarizing and reporting the results, with or without expert consultation. PRISMA provides best practice advice for presenting the search strategy and findings. The strategy for completing these steps was developed by the research team prior to completing the review, while allowing for flexibility in keeping with the exploratory nature of a scoping review. Per PRISMA guidelines, a protocol was not required to be registered prior to starting the review (14).

(1) Identifying the research question

The research question was developed by all authors through an iterative process. A preliminary search was carried out by the lead author on Medline to provide an approximate outline of the breadth and nature of studies on digital tools for ABI Assessment.

The primary question being asked was: What studies exist from the past 10 years that evaluate the use of digital technologies to screen for, assess and monitor the complications of ABI across the world?

Secondary questions included:

(1) What were predominant technologies being employed in these studies?

(2) Did type and frequency of different technology change over time?

(3) What patient cohorts were included in these studies, e.g. demographic, disease severity, underlying aetiology etc.

(4) What complications of ABI were predominantly being studied.

(5) What were the nature of the studies being performed.

(2) Identifying relevant studies

Prior to developing a search string, definitions for the key concepts of the study were agreed upon. ABI was defined as any individual who suffered an injury to the brain that was not developmental in nature or acquired at birth (15), due the unique presentation and specific needs of individuals with stroke (16), it was agreed not to include this cohort in the scoping review. Digital health technologies were defined in accordance with the U.S. Food and Drug Administration (FDA) as encompassing mobile health (mHealth), health IT, wearable devices, telemedicine, and AI-powered tools for healthcare assessment and monitoring (17). Assessments were defined as any method to screen for, evaluate, quantify or monitor ABI or its complications. The context was defined as any digital technology being used to aid assessment, monitoring or screening tests on individuals with ABI in any health setting.

A systematic search strategy was developed by all authors a Priori. The search string was developed to capture all studies reported across 3 databases: Medline, EMBASE and Scopus. The search string was constructed with an academic librarian using a combination of keywords, synonyms, and subject headings, tailored to each database's unique indexing system and functionalities. Terms related to "digital tools" (e.g., "websites," "internet," "telemedicine," "mobile applications," "digital platforms"), ABI (e.g., "acquired brain injury," "traumatic brain injury," "stroke," "brain trauma"), and clinical processes (e.g., "screening," "assessment," "monitoring") were combined using Boolean operators ("AND," "OR") to refine results. Through an extensive process of trial searches and refinement a comprehensive list of search terms and synonyms were collated to be included, this was further refined through a search for other keywords through reviewing relevant citations of screened articles. Full details of the search string can be found in the supplementary materials.

The search string was constructed with an academic librarian using a combination of keywords, synonyms, and subject headings, tailored to each database's unique indexing system and functionalities. Terms related to "digital tools" (e.g., "websites," "internet," "telemedicine," "mobile applications," "digital platforms"), ABI (e.g., "acquired brain injury," "traumatic brain injury," "stroke," "brain trauma"), and clinical processes (e.g., "screening," "assessment," "monitoring") were combined using Boolean operators ("AND," "OR") to refine results. Full details of the search string can be found in the supplementary materials.

A strategy for including Gray Literature was confirmed A Priori. Scopus was utilized for its innovative feature that searches across multiple pre-print databases, Embase's feature for

screening for conference abstracts was implemented, which were then used to search for full text articles both published and unpublished. As well as research databases , 4 clinical trials registries were searched using broad search terms: the International clinical trials registry, clinicaltrials.gov, the Eu Clinical trials register and the UK's ISTRCN (originally called International Standard Randomised Controlled Trial Number).

(3) Developing criteria for appropriate sources of evidence

The criteria for including articles in the process of charting and data mapping were decided by all authors following the preliminary search.

The inclusion criteria were all studies that:

1. Were published in English (the language of the study authors)
2. Focused on digital health tools (18,19) for screening, evaluating, or monitoring ABI symptoms (either solely or as part of a larger patient cohort).
3. Reported primary research findings.
4. Were published between January 2013 and December 2024 inclusive (this time window was chosen in light of the preliminary search, which concluded that technologies prior to this were outdated and less relevant to current standard of care).

The exclusion criteria were studies that:

1. Did not specifically address ABI or solely focus on participants with stroke.
2. Focused on non-digital methods of assessment without integrating digital tools, or when digital tools were not the focus of the evaluation.
3. Were narrative or systematic reviews, meta-analyses, editorials or opinion pieces lacking original research data.
4. Were descriptive, protocols only or still in development, i.e. they did not involve assessment of real human participants with ABI.
5. Did not have accessible full texts.
6. Included bespoke clinical devices that were not off the shelf or readily available digital technologies (for example, digital ICP monitors or robotic gait aids).

All articles capture in the systematic search were saved on a systematic review platform, Rayyan ™. The titles and abstracts of all articles were screened for relevancy by 2 authors working independently and blinded to each other's decisions. Following the title and abstract screen the 2 authors were unblinded and resolved any incongruent decisions unanimously,

with a 3rd tie-break author included if needed.

(4) Charting the data:

A table of relevant information to chart was developed as an iterative process based on preliminary searches in line with the Arksey and O'Malley framework. Key information included was: The 1st author, year of publication, nature of the technology, area of assessment, aim of the study, details of participants' diagnosis and demographics, the methodology of the study, primary outcome measures and key findings of the study. An evaluation of the quality of studies was not performed as this was beyond the remit of this study's question and the nature of a scoping review.

(5) Collating, summarizing and reporting the results.

Data was analysed to identify the predominant research themes, technologies used, primary outcome measures and key findings; this was presented as a table subdivided by theme, specific technology employed and assessment method.

Results:

Figure 1 is a PRISMA-SCr flowchart describing the results from the review and selection process**.** Detailed information on search results from each source of evidence can be found in the multimedia appendix under: (Search strategy and definitions).

Figure 1 PRISMA-SCr flowchart outlining the results from the review and selection process**.**

[a] Excluded due to subject not fitting review criteria, i.e. studies that do not evaluate the use of digital technology for clinical assessment.
[b]Excluded due to design or participants not fitting review criteria, i.e. studies which do not include human participants with ABI, or review studies.

Population Characteristics and Study Types

The median number of participants with ABI in each study was 25. There were 44 studies with healthy controls or participants without an acquired brain injury, the median number of control participants in these studies was 50.

Table 1 outlines the types of study and ABI cohort sample sizes, more detail on the design, methods and participant characteristics of specific studies can be found in the supplemental table in the appendix.

Figure 2 illustrates the participants included divided by etiology and injury severity. The majority of articles described their population as adults, 6 studies investigated paediatric participants only, 8 studies specifically included military personnel or veterans and 12 studies included athletes or individuals with sports related TBI solely. More detailed information on each studies characteristics may be found in the multimedia appendix (supplemental table).

Table 1: Study divided by type and ABI cohort size

Variable	Value: n (%)	References
Study Type		
Randomized Control Trials	5 (6)	
ABI cohort only	5 (6)	(19–23)
Cohort Studies	35 (40)	
ABI cohort only & no comparator assessment[a]	15 (17)	(24–37)
Inc. non-ABI controls with no comparator[a]	4 (4)	(38–41)
Inc. comparator assessment with ABI cohort only	4 (4)	(42–45)
Inc. non-ABI controls & comparator	12 (14)	

Cross sectional Study	42 (48)	
ABI cohort only & no comparator assessment[a]	4 (4)	(46–61)
Inc. non-ABI controls with no comparator[a]	15 (17)	(62–77)
Inc. comparator assessment with ABI cohort only	6 (7)	(78–83)
Inc. non-ABI controls & comparator	17 (19)	(84–100)
Qualitative Study	4 (4)	(101–104)
Retrospective review	2 (2)	
Included non-ABI cohort	2 (2)	(105,106)
ABI Cohort Population Size		
<20	29 (33)	
20-40	27 (31)	
41-100	18 (20)	
101-200	12 (14)	
>200[b]	2 (2)	

n = number of studies, (%) = percentage of included studies.

[a] Comparison of studied tool/assessment to a different assessment was not a primary outcome

[b] Both studies were retrospective reviews

Fig 2: Characteristics of Participants: Etiology of ABI, TBI Severity and non-ABI cohort.

[a] Studies included varying proportions of participants with TBI, encephalitis, ischemic stroke, haemorrhagic stroke, neoplasm, epilepsy or were unspecified. Single etiology involves participants with tumour (43) or focal epilepsy(31)

[b] Co-morbid cohorts included participants orthopaedic injuries, pain syndromes, psychosis, a history of trauma or mild cognitive impairment. Healthy pertains to individuals specifically identified as being "healthy" cohorts and undifferentiated members of the public. Mixed included both healthy and comorbid participants without ABI or TBI.

Digital Technologies

The majority of studies (n =45) focus on the use of smartphone (n=37) or tablet computer (n=8) based platforms for assessment of individuals with ABI. All of these studies specified that they used a proprietary or commercial application (app) to carry out assessments. Twenty-three studies describe computer based (n=11) or web (n=12) based tools; 11 studies employed a telemedicine or teleconferencing platform, 9 studies used a virtual reality (VR) platform which included computer and VR eyewear. Five studies described using machine learning or artificial intelligence techniques alongside either a smartphone, tablet computer, computer or web-based platform. **Figure 3** illustrates the trends in technologies studied over time.

Figure 3: Trends in technologies studied over time.

Mapping the Evidence: Study Themes, Outcomes, and Key Results

Table 2: Summarizes the predominant research themes, technology platforms used, assessment types, main outcome measures and key findings of each report. A more detailed description of each study is included in the multimedia appendix (supplemental table).

Table 2: Description of assessment tools, outcomes and key findings, divided by theme and technology type (N=87)

Theme & Assessment	Author (Year)	Product	Outcome Measures	Main findings
1. TBI Detection or Screening (n=10)				
(i) Smartphone or Tablet Based Tools				
Speech analysis	Falcone M, (2013) (44)	LIBSVM – based platform	Sensitivity in mTBI screening vs expert assessment	Platform was 98% accurate in detecting mTBI vs expert screening
	Yadav N, (2016) (71)	Sphinx Toolkit	Timing and frequency differences in speech in TBI-C vs HC	SPHINX detected significant timing and frequency differences in TBI-C vs HC
Passive sensor analysis	Shelke S. (2021) (39)	TBI2Vec	Sensitivity in mTBI screening over time vs HC	The TBI2Vec model was sensitive at identifying mTBI, most accurate at 2d & 12 h post injury
Screening exam	Wilkerson GB. (2020) (89)	Flanker Test -app adapted	Test-retest reliability, correlation with symptoms on wellness survey in TBI-C	App-based Flanker Test had good reliability; scores correlated with reported symptom burden
(ii) Computer or Web Based Tools				
Online survey	Lequerica AH, (2018) (107)	OSU-BID	Completion rate; correlation with RPQ, PRQS, CSS	OSU-BID had an 89.4% completion rate; correlated with RPQ but not PRQS or CSS.
	Gardner RC, (2020)	OSU TBI-ID	Reliability across time, sensitivity in screening for TBI vs NACC-UDS screen	OSU-TBI-ID was reliable across time and more sensitive than NACC-UDS for identifying TBI.

	(90)			
	Sullivan KA,(2024) (108)	Qualtrics™, OSUTBI-ID	Completion rate, correlation of indices of TBI severity with symptom scales (inc. PCSS)	High completion rate (94% of responses included), indices of severity correlated strongly with PCSS etc.
CATI	Cuthbert JP, (2016) (41)	OSU-BIIM CATI	Retest reliability for cumulative, severity, and age-related indices of injury	Reliable for indices of most severe TBI, moderate for cumulative injury indices; poor for age indices.
Speech & facial expression analysis	Schultebraucker K, (2021) (91)	Parselmouth ™, Openface™	Correlation with WebNeuro ™ cognitive battery, in TBI vs HC	Both tools showed a strong correlation between abnormal speech/expression findings and WebNeuro scores
(iii) Telemedicine Based Tools				
Acute mTBI screening	Vargas BB, (2017) (79)	VGo™ Telemedicine Robot	Agreement of telemedicine screen for sports related mTBI vs on-field screen and RFP decisions	Near 100% agreement in SAC scores, K-D test times, mBESS scores and RFP. RFP decisions were consistent 100% of the time.
2. Symptom Assessment or Monitoring (n = 28)				
(i) Smartphone or Tablet Based Tools				
EMA for symptom monitoring	Sufrinko, A. M, (2019) (44)	Ilumivu ™ System -app	Response rate, correlation with PCSS, VOMS, cognitive screening, and recovery time	Mean EMA completion rate of 52.4%, recorded symptoms correlated with PCSS, VOMS and recovery time, but not cognitive screens
	Liu K, (2022) (33)	Healthstories Online™ -app	Completion rate, correlation of EMA symptom findings with HIT-6 scores.	EMA responses averaged of 2.5 entries per week, there was a strong correlation with HIT-6
	Ezekiel L, (2023) (109)	Proprietary Android App	Usability scores (SUS) and interview feedback, sensor reliability	Participants reported good usability; sensors found to be unreliable at capturing activity
	Ezekiel L, (2024) (104)	ThinkAloud™	Rate of EMA completion, themes from participant & therapist interviews	Mean EMA completion rate of 78%; broad range of themes derived from interviews, inc. understanding challenges, etc.
	Lazeron-Savu E, (2024) (31)	PsyMate™	Compliance and completion rate, changes in fatigue (DMFS) score at week 6, qualitative feedback	70% of participants used app, of whom 71% gave improved DMFS scores at week 6; EMA completion rate averaged 56%; reported to be useful for identifying triggers
EMA for psychological symptoms	Juengst SB, (2015) (35)	iPerform ™	Compliance with EMA prompts, satisfaction, and useability rating	Mean EMA completion rate was 73.4%; high satisfaction and useability ratings given, EMA reports strongly correlated with PHQ-9 & GAD-7

	Juengst SB, (2019) (110)	iPerform ™	Variability in symptoms across time	Reporting of all emotional, fatigue and associated symptoms fluctuated significantly across time
	Juengst SB. (2023) (59)	BAST-mHealth	Compliance with EMA prompts, agreement with "full" BAST scores	79.7% of participants completed >/= 80% of EMA prompts; no significant difference in results vs standard BAST
	Little JR, (2017) (20)	"mCare" App	Wellbeing score (GWS) and case management quality scores (CMQQ) in treatment (mCare) vs control (SOC) arm	No statistically significant change in GWS or CMQQ in either control or treatment arm. Participants reported app to be useful
	Forster SD, (2020) (25)	MovisensXS ™	Compliance rate, response variation over time, correlation between compliance and demographics	Mean EMA completion rate was 71.4%; there was significant fluctuation in responses across time, compliance not associated with age, depressive symptoms, or impairments
	Rabinowitz A, (2021) (27)	RealLife Exp.™ (LifeData Systems)	Response rate, association of various activities with reported affect (e.g. on PANAS, etc.)	Mean EMA completion rate was 17%; association of activities with affect varied by respondent
	Rabinowitz A, (2024) (26)	RealLife Exp. ™ (LifeData Systems)	Response rate, association of activities with reported affect (e.g. on PANAS, accomplishment scale etc.)	Mean EMA completion rate was 65%; association of activities with affect varied by respondent
	Sherer M (2024) (23)	Mood Tracker app, (iLumivu™)	PHQ-9 ad GAD-9 scores in treatment (receiving EMA) vs control (SOC) arm, compliance rate	No significant difference in emotional distress scores between treatment and control groups; mean EMA response rate was 80
Function +/- quality of life survey	Gvozdanovi AC, (2022) (42)	Vinehealth	Completion rate, participant feedback	Survey had low completion rate due to technical issues, participants reported it improved their care
	Shukla D, (2023) (81)	GOSE (adapted)	Agreement with the interview-based GOSE scores	Agreement of app-based questionnaire results compared with the interview results.
	Lumetta K, (2023) (82)	FACT (novel survey)	Correlation of responses on FACT survey with SCAT and PCSS	The impact of symptoms on function recorded via FACT correlated strongly with worse SCAT and PCSS scores
Survey on activity with actigraphy	Huber DL, (2019) (57)	mHealth Survey (MS), Fitbit	Activity levels in TC vs HC. Correlation between self-reported activity and actigraphy	TC demonstrated less activity on actigraph monitoring vs HC. Moderate correlation between self-reported activity and actigraphy
	Wen PS. (2021)	MOVES™ App	Study retention, satisfaction rate; correlation of activity with PART-O scores; activity rate in TBI-C vs HC	Study had 75% retention rate, high satisfaction; activity had moderate correlation with PART-O scores; TBI, HC

	(58)			
	Lee MJ, (2021) (48)	MySleepScript App	Time to completion, sleep quality scores in TBI cohort vs other ABI	Mean completion time was 16 min, TBI cohort reported worse sleep quality scores vs other ABI
Survey on sleep (+/- actigraphy)	Morrow EL (2024) (28)	Actigraph GT9X™ activity monitor	Sleep duration, rate of "wakeups" vs sleep quality reports. Accuracy in self-reporting in TC vs HC	Strong correlation between reported sleep duration and actigraphy in both groups, no correlation between reported sleep quality or actigraphy in either group.
EMA and heart rate variability (HRV) monitoring	Nabasny A, (2022) (38)	BAST mHealth™ and Elite HRV™ apps; Polar 10 HR sensor.	Compliance with HRV monitor, covariance between HRV and EMA neuro-behavioural (NB) symptom responses	There was high compliance (85% of HRV scheduled recordings completed) HRV did not show consistent correlation with reported NB symptoms.
Predicting symptoms	Schultz LS (2024) (32)	Mindstrong Discovery™	Rate uptake (consent to install app) and transfer of data, prediction of depression (compared to PHQ-9 etc.)	93.8% of subjects consented and installed app, of whom 93.3% had at least 1 data transfer; sensor analysis predicted depression greater than chance
(ii) Computer or Web Based Tools				
	Suffoletto B, (2013) (19)	TIPS – software not named	Changes on symptom burden scales (RPQ, and PHQ-9) in IA (CATM assessment and advice) VS CA (SOC)	Participants in IA tended to report fewer and less symptoms at trial end, but not statistically significant
CATM Survey	Anthony CA, (2015) (24)	CSSS – software not named	Repeatability coefficient of symptom scores across time.	CSSS were poorly repeatable across time (mean 23.6 day follow up).
	Schoenfeld R, (2022) (34)	ConText - Software not named	Completion and retention rate of CATM-survey, correlation with PCSI	High completion and retention rate, correlated with initial PCSI
CATI	Wong AK, (2014) (68)	CAT CPI	Completion rate of online vs CAT, factors associated with choice off online VS CATI	CAT-CPI had a 34% completion rate, there was no significant difference in completion rate between online survey or CATI
	Karvandi E, (2024) (29)	Onlinesurveys.ac.uk	Number of eligible patients, follow-up rates, survey response rates	The 1st survey had a 67% completion rate, 47.5% of participants completed all three; reported to be useful, acceptable & user friendly
Online survey	Shaikh N, (2021) (49)	BIST	Internal construct validity, dimensionality, Rasch analysis findings	BIST demonstrated acceptable model fit, good reliability, and uni-dimensionality for screening mTBI symptoms and quantifying severity
3. Clinical or Physical Examination (n = 18)				

(i)	Smartphone or Tablet-Based Tools			
Gait, balance or posture examination	Rhea CK, (2017) (43)	AccWalker ™ App	Sensitivity to neuromotor changes in TBI-C; correlation with cognitive tests (inc. RBANS etc.)	App was sensitive to neuromotor changes and correlated strongly with cognitive assessments
	Rhea CK, (2022) (111)	AccWalker ™	Comparison of movement variability (MV) in TBI-C vs CC	The app demonstrated a significantly higher MV in TBI-C compared to HC
	Feigenbaum LA, (2019) (112)	Cane-Sense™	Correlation of Cane-Sense & mBESS scores in pre and post injury TBI-C	Cane-sense more likely to be abnormal in post injury mTBI cohort than mBESS scores
	Manor B, (2019) (47)	TeamStudy ™	Correlation of TBI burden and LOC history with balance scores	Both a high TBI burden and LOC history correlated with balance scores
	Kis M, (2020) (72)	EQ balance™, & Sway Balance™	Safety; agreement in balance findings between apps and difference in findings between TBI-C vs HC	Both apps were safe, with strong consistency in results, balance scores in TBI-C were worse than HC
	Dummar MK, (2024) (60)	Sway Balance™	Difference in mBESS scores in TBI-C vs HC, changes over time, correlation with SOT	Sway™ identified significant difference in mBESS scores in TBI-C vs HC, stable findings over time, no correlation between mBESS scores & SOT scores
	Tirosh O, (2024) (74)	TelePhysio™	Difference in postural sway metrics in TBI-C vs HC	App identified greater sway metrics in TBI-C vs HC
Pupillary Light Response (PLR) exam	Carrick FR, (2021) (106)	BrightLamp Reflex ™	Difference in PLR parameters in TBI-C vs CC	Significant differences in multiple PLR parameters in TBI-C vs CC; PLR also varied across age and gender
	McGrath LB, (2022) (69)	PupilScreen™	Predictive value of abnormal PLR findings to identify TBI-C vs HC.	>90% positive predictive value for TBI based on PLR findings, high within-group reliability
	Maxin AJ, (2023) (113)	PupilScreen™	Sensitivity identifying PLR abnormalities in TBI-C vs HC, compared to pupillometry	PupilScreen™ app was more sensitive for detecting PLR abnormalities in TBI-C (vs compared to pupillometry
	Dutta P, (2024) (77)	Reflex Pro™	Difference PLR findings in TBI-C vs HC	Reflex Pro™ identified significant differences in PLR parameters in TBI-C vs HC
(ii)	Computer or Web-Based Tools			
Analysis of limb movement	Mobbs A (2024)	DeepLabCut ™	Agreement of ML-based analysis, and clinician rated limb movement abnormality	ML rating of abnormal gait strongly agreed with clinician scores

	(94)		during gait	
(iii) Telemedicine Platform (TMP)				
Adapted clinical exam	Llamas-Rojas R (2023) (37)	FMA-TV	Agreement between FMA-TV and in person FMA (CIC and WKI)	Substantial agreement between FMA-TV and in-person FMA
	Soria MZ, (2023) (83)	OMES, Google Meet™	Reliability of TMP OMES with in-person OMES	Excellent reliability between OMES scores from TMP and in person assessments,
(iv) Immersive Virtual Reality (VR) Based Tool				
Balance or Gait assessment	Teel EF, (2015) (86)	VR Balance Module	Correlation of VR scores and pressure plate findings	VR based balance scores correlated strongly with pressure plate findings
	Sarker P (2022) (51)	HTC Vive Pro, Sranipal SDK,	Sensitivity in screening for TBI-C vs HC; sensitivity compared to VOMS scores	VR headset eye tracking was more effective at delineating TBI-C over HC than VOMS findings
	Robitaillea N, (2016) (65)	VrAI	Difference in walking fluidity in TBI-C vs HC; subject feedback	Walking fluidity less dynamic in TBI-C vs HC, mostly well tolerated, one subject suffered nausea
Visual neglect assessment	Painter DR, (2023) (54)	The Attention Atlas	Correlation with clinical assessments for neglect; feasibility	VR search task correlated well with clinical assessment for neglect; feasible study protocol
4. Cognition or Memory (n = 24)				
(i) Smartphone or Tablet-Based Tools				
Battery of assessments	Yang S, (2017) (88)	Brain Check™	Sensitivity screening for cognitive deficits in TBI-C vs HC	All tests sensitive in identifying cognitive deficits in TBI-C vs HC
	Rice V, (2019) (75)	ANAM 4, VA	Difference of ANAM subscales & VA voice analysis findings in TBI-C vs HC	ANAM mood subscale significantly different in TBI-C vs HC, no difference seen in VA or other ANAM subscales
	Rebchuk A, (2020) (105)	NIHTB-CB	Accuracy of NIHTB-CB scores in ABI-C (mTBI & stroke) vs NIH-BI scores	NIHTB-CB overestimated fluid and total cognition in ABI-C, otherwise accurate vs NIH-BI
	Spreij LA, (2020) (100)	d-NPA™	Completion rate, validation through comparing HC results to known paper-based test percentiles	d-NPA had a 94% completion rate, 34% of HCs scored in 10th percentile for paper-based norms
Novel or adapted assessment	Wallace SE, (2019)	STAN	Correlation of STAN with MoCA and CLQT; feedback on comfort	Moderate correlation with MOCA & CLQT; mixed comfort levels reported

	(80)			
	Chen PM, (2024) (84)	ImPACT-QT	Completion time, usability ratings	Mean completion: 9.3 minutes, most participants reported test was easy to understand (93%)
Task-based assessment	Fischer TD, (2016) (87)	King-Devick (KD) ®	Response time, sensitivity screening for mTBI vs standard assessment; differences in TBI-C, orthopaedic cohort and HC	TBI-C responses were significantly slower vs orthopaedic and HC; similar sensitivity and specificity vs standard assessments
Memory training & testing	Morrow EL (2024) (50)	Memi™	Completion rate, usability (SUS), interview feedback	MEMI had a 98% completion rate, most participants reported it was easy to use and helpful
AR-based screening	Mendez-Lopes M, (2024) (63)	SLAM™-based proprietary app	Usability (UAS), interview feedback, time to task completion	UAS scores from TBI-C were positive but slightly lower than HC; mean time to complete tasks was longer in TBI-C vs HC
(ii) Computer or Web Based Tools:				
Task-based screening	Canty, AL, (2014) (53)	VRST	Correlation of VRST scores with occupational activity (OA) and cognitive battery (inc. HVLT revised, TMT A + B, etc.)	VRST correlated with OA, and mental flexibility and verbal fluency scores on standardised battery, high usability ratings
	Goverover Y, (2015) (66)	Actual Reality	Completion rates, performance times, number of errors in TBI-C Vs HC	TBI-C took significantly longer to complete the task, with more errors vs HC
	Martínez-Pernía D, (2017) (46)	Serious Game	Completion and error rates, quantitative and qualitative user feedback	Participants had no commission, omission or preservation errors, therapists and ABI-C reported test was useful and easy to use
	Van Nostrand (2019) (64)	Proprietary computer based assessments	Correlation between performance and mTBI	Individuals with mTBI demonstrated worse results
	Nadler T, (2022) (93)	IBPT	Time and cues needed to complete, correlation with executive function (EF) battery in TBI-C vs HC	TBI-C required significantly more time and cues to complete IBPT, this moderately correlated with EF battery scores
	Lencsés A (2024) (96)	Virtual Week	Prospective and retrospective memory (PM and RM) scores in ABI-C vs HC	ABI cohort had significant PM and RM deficits compared to HC across tasks
Battery of assessments	Spreij LA, (2021)	d-NPA ™	Performance stability in ABI-C vs HC in adapted battery (inc. RVLT, TMT A+B, SCWT, etc.)	Significantly reduced in performance stability in ABI-C vs HC, across all tests and over time

	(76)			
	Del Giovane M, (2023) (55)	Cognitron ™	Correlation of tests with MOCA and RBANS in TBI-C	Cognitron Battery correlated strongly with MoCA and RBANS in TBI-C
	Pellinen (2024) (30)	Cogstate™ Brief Battery (CBB)	Completion rate of cognitive battery, characteristics associated with non-completion	CBB had a 61% completion rate; non-completion was associated with sex, gender, race and learning disability
Adapted screening test	Schatz P, (2013)	ImPACT	Sensitivity and specificity in screening for cognitive issues in TBI-C vs HC.	Web-based ImPACT screen was sensitive and specific for mTBI with cognitive issues vs HC
(iii) Immersive Virtual Reality (VR) Based Tool				
Task based assessment	Okahashi, S (2014) (67)	VSTR	Shopping-task completion rate, time to completion, subjective difficulty rating in TBI-C vs HC	VSTR completion rate was similar in TBI-C and HC, TBI-C took longer to complete; HC was more likely to rate certain tasks as difficult
	Seton C, (2023) (61)	SeaHero Quest (SHQ)	Distance to navigate to virtual end point in TBI-C vs HC; correlation with SDS	TBI-C took longer to reach waypoint on SHQ, this correlated with the SDS
Adapted battery of assessments	Teel EF, (2016) (52)	HeadRehab	Sensitivity and specificity in identifying cognitive & sensorimotor deficits in TBI-C vs HC	VR cognitive and sensorimotor modules were sensitive & specific for detecting deficits in TBI-C vs HC
	Shen J, (2022) (92)	VR CAT	Correlation with NIH-T scores and feedback on satisfaction and realism	Composite VR CAT scores correlated with NIH-T; satisfaction reports largely positive
	Malegiannaki AC, (2024) (102)	CBAAD	Sensitivity screening for attentional dysfunction (AD) in TBI-C vs HC; correlation with the ARCES	CBAAD was sensitive screening for AD; it correlated well with ARCES
5. Language and communication (n = 4)				
(i) Telemedicine Platform (TMP)				
Discourse assessment	Cruse N, (2024) (40)	Zoom™	Feasibility, mean completion time, differences in discourse quality (grammar & proposition analysis) in TBI-C vs HC	Assessments completed quickly, without technical difficulties; reduced quality of narrative discourse in TBI-C vs HC
	Turkstra LS (2023) (78)	Aphasia bank, Internal TMP	Reliability of discourse assessment via TMP vs in person	Reliable findings of discourse quality in TMP vs in-person assessments
Communication assessment	Rietdijk R, (2017)	Skype™, adapted LTCA	Difference in LTCA score on TMP vs in-person assessments (performed on same	There were no significant differences on LTCA scores on TMP vs in-person

	(45)		day)	assessments.
	Rietdijk R, (2018) (21)	Skype™, adapted MSC & MPC	Task completion, interrater reliability, correlation with in-person assessment	There were no significant differences in assessment findings between telemedicine and in-person assessments. Skype was used successfully with 17/19 participants
6. Comprehensive Consultation (n = 4)				
(i) Telemedicine Platform (TMP)				
TMP-based consultation	Marckmann C, (2020) (103)	TMP not named	Service uptake, wait times, subject satisfaction (Likert scale), est. cost-savings vs in-person	Median 1-day wait for consultation post-TBI, mean 54.3 miles travel saved, high program uptake (80% of trainers surveyed used the service); mean satisfaction was 4.75/5
	Ellis MJ, (2019) (102)	Cisco Jabber	Description of service & subjects; est. cost-savings vs in-person	Significant cost saving compared to in-person clinic
	Elbin RJ, (2021) (22)	Videoconferencing software not named	Caregiver reported therapeutic alliance; patient satisfaction	Similar levels of therapeutic alliance reported; similar satisfaction scores in TMP and in-person group
	Caze Ii T, (2020) (101)	TMP not named (internal program)	Description of service and subject characteristics	Median time from TBI to 1st visit: 21 days, average of 2.2 visits, 55.6% of subjects cleared to return to learn/play at a median of 15.5 days

Key Abbreviations (comprehensive abbreviation list can be found in supplemental table)

TBI	Traumatic Brain injury
ABI	Acquired Brain Injury (Cohort may include TBI if at least one other etiology included)
TBI-C	TBI Cohort (participants with TBI)
ABI-C	ABI cohort (participants with ABI)
HC	Healthy Controls
CC	Co-morbid controls
IA	Intervention Arm of a clinical trial (can include a novel/adapted assessment as the “intervention” – per WHO guidelines of Ct”)
CA	Control ARM of a clinical trial
CATM	Computer assisted text messaging
CATI	Computer Assisted Telephone Interview
SOC	Standard Of Care
TMP	Telemedicine platform
ML	Machine Learning
RFP	Return to field of play
EMA	Ecological momentary assessment (regular real time screening of symptoms)(114)

Discussion:

This scoping review reveals a growing and diverse range of digital tools and platforms that have been investigated to better assess, evaluate and monitor for ABI symptoms and complications across various populations and clinical settings. Advances in mobile and web-based platforms, telehealth, machine learning, and virtual reality (VR) have facilitated the development of innovative solutions aimed at improving accessibility and effectiveness in ABI care.

Screening or Diagnosis of Acute mTBI

A major theme identified was the use of technology to aid the screening of mTBI or concussion; particularly sports-related concussion (SRC).

Several novel techniques to aid screening have been demonstrated: Falcone et al. and Yadav et al. describe the use of machine learning (ML) software to analyze speech patterns in participants with mTBI compared to controls; both demonstrated high sensitivity for identifying mTBI (71,85). Similarly, Schultenbrauck et al. employed ML platforms to analyse speech and facial expression differences in mTBI cohorts compared to healthy controls, with significant differences between groups (91). Shelke et al. described the use of passive smartphone sensor data to identify digital biomarkers for concussion; this was particularly sensitive at day 2 post injury (39). Most of these novel techniques were assessed in pilot studies with <20 participants with ABI (except for Yadav et al. who included 98 participants with SRC)(71). Wilkerson et al and Varga adapted previously validated concussion screening tests for smartphone and telemedicine use respectively, both demonstrating effectiveness in their initial cohorts (79,89).

As well as the assessment of acute TBI, several studies describe the use of web-based of computer-assisted telephone surveys to screen for a history of TBI and the burden of injury. Most studies demonstrated high compliance and completion rates, and reliable findings across time or compared to surveys on symptom burden (90,95,98,115).

Physical Examination

Physical examination is a key part of any assessment of ABI; it is important when screening for TBI as well as identifying clinical signs associated with complications of ABI such as vision, balance and movement deficits. Many studies looked at how in-person clinical examinations can be replicated through a digital medium, while others sought to use technology to assist in the analysing the clinical findings.

A range of studies included the use of smartphone applications to facilitate the assessment of the pupillary light reflex, using the phones video and flash function, as well as digital analysis of pupillary parameters such as average speed of constriction or dilation, to the differentiate between individuals with and without mTBI. These were performed either retrospectively (106), or in the acute setting to aid in the screening for concussion (69,77,116). All studies demonstrated significant differences in mTBI PLR findings compared to controls. These findings show promise in providing another assessment tool to screen for concussion, which is relatively cheap and easy to learn to use, compared to traditional pupillometry (106).

Several studies investigated the use of smartphone apps which employ built-in sensors such as accelerometers and gyroscopes, to measure gait, balance and/or posture (43,47,56,60,72,117). Most apps were found to consistently identify movement abnormalities in ABI cohorts, although they did not always correlate well with other measures of symptom burden (60). Similar assessments are described using the built-in sensors of VR headsets (51,65,86) and machine-learning video analysis of gait (94). Digital tools such as these may help to provide more objective, consistent examination findings than a simple clinical examination although while lacking the utility of a dedicated gait lab in complex cases.

A VR platform was used to look for visual inattention in ABI by Painter et al. with “The Attention Atlas”. This small pilot study demonstrated a promising correlation with more traditional assessments for inattention and was well tolerated.

Llamas-Rojas et al. and Soria MZ et al. both adapted standardized in-person assessments for use via telemedicine platform (the Fugl-Meyer and Oral Myofunctional Evaluation) respectively, and found strong reliability with in person assessments (37,118); although participant populations were small.

Symptom Assessment and Monitoring

This review identified a large body of research on the use of digital tools for screening, evaluating and monitoring symptoms. Numerous studies looked at the use of online or computer adapted telephone and test-message based surveys (19,24,29,34,49,119). Survey completion rate was mixed; although these techniques may be a useful additional tool to screen for complications and symptoms, more research is needed to better understand how to improve engagement and compliance across this diverse population.

Digital tools may help identify individuals' function and quality of life in ABI. Lumetta et al. developed a novel survey screening for functional complications of TBI (82). Similarly, Shukla et al and Gvozdanovi et al investigated the use of online surveys to evaluate quality of life and functional outcomes, however there were mixed rates of completion (42,120).

Numerous studies assessed symptom monitoring through smartphone-based ecological momentary assessment (EMA) applications. EMA pertains to the real-time recording of experiences, behaviours and symptoms in an individual's natural environment (114). Many studies prompted participants to provide responses to questions on current or recent sleep quality, symptom burden and/or activity levels (31,33,44,50,56–58,104,109,121); some of these investigations paired the EMA surveys with wearable sensors (such sleep and heart rate monitors) (28,48,57,58). Other studies implemented EMA to track emotional or psychological symptoms (20,23,25,27,35,36,122,123). Most EMA interventions had good to excellent compliance rates during the study period (particularly when paired with phone calls from researchers to encourage engagement); many studies reporting positive feedback on ease of use and usefulness (29,48,121). When studies assessed the use of EMA self-assessment as therapeutic tool there was no evidence of improved symptoms compared to standard of care (20,23).

Cognitive and Memory Assessment

A variety of smartphone, computer-based, and VR tools were used to assess cognitive function post-TBI. Many adapted an previously validated assessment or battery of tests for digital use; with most demonstrating strong correlation with in-person or paper based assessments (30,55,75,76,88,100,105). A number of studies developed novel assessment tools designed specifically for tablet computer use (80,84,87); others monitored participants' completion of a variety of tasks in a virtual (53,67,93,96,124,125) or augmented reality (63) environment; and compared findings to healthy controls or standardized cognitive tests; with most found to be useful and well tolerated in the context of the cohort studied.

Language or Communication Assessment

Digital tools for language and communication assessment were consisted of previously tools and assessment techniques adapted for telemedicine platforms. Telemedicine platforms were found to be reliable in the assessment of discourse quality when compared to healthy controls (40) and in person assessments (126). Telemedicine platforms were also found to be suitably affective in the performance of standardized communication assessments (45,127). However, like other areas, the populations studied tended to be small.

Comprehensive Consultation

Telemedicine platforms were extensively used to aid in comprehensive consultations and were shown to be valuable in the context of remote or underserved populations (22,101–103). The articles included in our review were pilot and/or qualitative studies, with outcome measures centred on user-satisfaction, cost-effectiveness or feasibility. Several studies indicate high levels of patient satisfaction with telehealth services, and significant estimated savings on travel costs (103,128). Despite this, telehealth platforms often rely heavily on internet connectivity and patient familiarity with digital technology, highlighting the need for solutions tailored to diverse settings and populations.

Limitations of Current Evidence

A broad range of assessment tools and technologies have been evaluated, but most studies involved small, heterogeneous populations, limiting the generalizability of their findings. Sample sizes were often insufficient to ensure statistical power, with many studies appearing to be exploratory or pilot in nature. Furthermore, only 5 randomized controlled trials (RCTs) were identified, and these were primarily feasibility studies rather than rigorous efficacy trials.

Study design and methodology was highly variable. Many studies employed cross-sectional or observational designs without control groups, reducing the ability to establish feasibility or efficacy. The lack of standardized outcome measures across studies make it challenging to compare findings or draw broader conclusions about the efficacy of specific digital interventions.

Lastly, participant recruitment often lacked diversity in terms of demographic and clinical characteristics, with many studies focusing predominantly on mTBI or narrow demographic groups, such as adolescents or military personnel, thus study findings may not be applicable to broader ABI populations.

No study was identified, which combined multiple assessments into one platform, the studies which describe the use of telemedicine platforms for comprehensive consultation go into little detail about the assessments carried out. While many digital tools are promising on their own, it would likely be more efficient and cost effective to combine these on one platform.

Despite these limitations, the studies highlight the promising potential of digital tools in this field, underscoring the need for larger, more robust trials to validate their use and ensure equitable access.

Strengths and Limitations of This Scoping Review

This review provides a comprehensive overview of digital innovations in ABI assessment and monitoring in the past decade, highlighting key trends and innovation. However it is limited due to our focus on English language studies, which likely excludes valuable research from non-English speaking regions. Additionally, as a scoping review without a formal assessment of quality, we are limited in evaluating the efficacy of specific technologies or platforms or predicting their impact on a wider population. Though multiple papers were evaluated a thorough synthesis was not carried out and a future step may include a dedicated meta-analysis.

Conclusion:

This review highlights major strides in the application of technology to help improve how individuals with ABI are screened and assessed. There is a particular focus on mTBI with less published on assessments of patients with moderate severe TBI, or other aetiologies of ABI. The majority of studies performed to date include small numbers of patients, designed as pilot or feasibility studies, thus more rigorous studies with larger populations are required to better understand the efficacy of various technologies. Future developments should also consider the assessment of less-explored complications of ABI, and leverage assessments across multiple domains, to provide a holistic care.

The findings from this review may inform the development of further digital tools to provide a comprehensive and equitable approach to clinical assessment in patients who suffer from ABI, that is accessible and efficacious for all.

Acknowledgements

Carl O'Brien, 1st Author, completed preliminary search, screening, data charting and synthesis, write up and proof reading; co-developed review protocol. Aoife Murray, 2nd Author, completed screening and proof reading, co-developed review protocol. Gerry McManus, 3rd Author, academic librarian, developed search strategy and co-developed review protocol. Chantel Debert, Supervising author, completed screening (tie-break author), proof reading and co-developed review protocol.

Conflicts of Interest

The authors declare no conflict of interest

Funding

Access to Medline, Embase and Scopus was available to authors through affiliations with

university College Dublin and University of Calgary.

References:

1. Schrieff-Elson LE, Steenkamp N, Hendricks MI, Thomas KGF, Rohlwink UK. Local and global challenges in pediatric traumatic brain injury outcome and rehabilitation assessment. Childs Nerv Syst. 2017 Oct;33(10):1775–84.

2. Barbiellini Amidei C, Salmaso L, Fedeli U, Saia M. Traumatic brain injury incidence and mortality: a large population-based study. J Neurol. 2024 Jul;271(7):4430–40.

3. Eliassen M, Arntzen C, Nikolaisen M, Gramstad A. Rehabilitation models that support transitions from hospital to home for people with acquired brain injury (ABI): a scoping review. BMC Health Serv Res. 2023 Jul 31;23(1):814.

4. Albrecht JS, Kumar A, Falvey JR. Association Between Race and Receipt of Home- and Community-Based Rehabilitation After Traumatic Brain Injury Among Older Medicare Beneficiaries. JAMA Surg. 2023 Apr 1;158(4):350.

5. Guan B, Anderson DB, Chen L, Feng S, Zhou H. Global, regional and national burden of traumatic brain injury and spinal cord injury, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. BMJ Open. 2023 Oct;13(10):e075049.

6. Capizzi A, Woo J, Verduzco-Gutierrez M. Traumatic Brain Injury. Med Clin North Am. 2020 Mar;104(2):213–38.

7. Marklund N, Bellander B -M., Godbolt AK, Levin H, McCrory P, Thelin EP. Treatments and rehabilitation in the acute and chronic state of traumatic brain injury. J Intern Med. 2019 Jun;285(6):608–23.

8. Van Der Vlegel M, Mikolić A, Lee Hee Q, Kaplan ZLR, Retel Helmrich IRA, Van Veen E, et al. Health care utilization and outcomes in older adults after Traumatic Brain Injury: A CENTER-TBI study. Injury. 2022 Aug;53(8):2774–82.

9. Schrieff-Elson LE, Steenkamp N, Hendricks MI, Thomas KGF, Rohlwink UK. Local and global challenges in pediatric traumatic brain injury outcome and rehabilitation assessment. Childs Nerv Syst. 2017 Oct;33(10):1775–84.

10. Piedade SR, Hutchinson MR, Ferreira DM, Cristante AF, Maffulli N. The management of concussion in sport is not standardized. A systematic review. J Safety Res. 2021 Feb;76:262–8.

11. Jose AP, Kaushik A, Tange H, Van Der Weijden T, Pandey N, Sharma A, et al. Redesigning telemedicine: preliminary findings from an innovative assisted telemedicine healthcare model. BMC Prim Care. 2024 Oct 23;25(1):380.

12. Bhavnani SP, Narula J, Sengupta PP. Mobile technology and the digitization of healthcare. Eur Heart J. 2016 May 7;37(18):1428–38.

13. Smith BG, Tumpa S, Mantle O, Whiffin CJ, Mee H, Solla DJF, et al. Remote Follow-Up Technologies in Traumatic Brain Injury: A Scoping Review. J Neurotrauma. 2022 Oct;39(19–20):1289–317.

14. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med. 2018 Oct 2;169(7):467–73.

15. Rees L, Marshall S, Hartridge C, Mackie D, Weiser M. Cognitive interventions post acquired brain injury. Brain Inj. 2007 Jan;21(2):161–200.

16. Singh RJ, Chen S, Ganesh A, Hill MD. Long-term neurological, vascular, and mortality outcomes after stroke. Int J Stroke. 2018 Oct;13(8):787–96.

17. FDA. What is Digital Health? 2020.

18. Teasell R, Marshall S, Cullen N, Janzen S, MacKenzie H, Bayley M. Evidence-Based Review of Moderate to Severe Acquired Brain Injury [Internet]. Erabi; 2022. Available from: https://erabi.ca/wp-content/uploads/2018/10/ERABI-Module-1-V15-Updated-Jul-20-2022-PLAIN-TEXT.pdf

19. Suffoletto B, Wagner AK, Arenth PM, Calabria J, Kingsley E, Kristan J, et al. Mobile phone text messaging to assess symptoms after mild traumatic brain injury and provide self-care support: a pilot study. J Head Trauma Rehabil. 2013;28(4):302–12.

20. Little JR, Pavliscsak HH, Cooper MR, Goldstein LA, Fonda SJ. Does Mobile Care ('mCare')

Improve Quality of Life and Treatment Satisfaction Among Service Members Rehabilitating in the Community? Results from a 36-Wk, Randomized Controlled Trial. Mil Med. 2018 Mar 1;183(3–4):e148–56.

21. Rietdijk R, Power E, Brunner M, Togher L. The reliability of evaluating conversations between people with traumatic brain injury and their communication partners via videoconferencing. Neuropsychol Rehabil. 2020 Jul 2;30(6):1074–91.

22. Elbin RJ, Stephenson K, Lipinski D, Maxey K, Womble MN, Reynolds E, et al. In-Person Versus Telehealth for Concussion Clinical Care in Adolescents: A Pilot Study of Therapeutic Alliance and Patient Satisfaction. J Head Trauma Rehabil. 2022 Aug 1;37(4):213–9.

23. Sherer M., Juengst S., Sander A.M., Leon-Novelo L., Liu X., Bogaards J., et al. Mood Tracker: A Randomized Controlled Trial of a Self-Monitoring Intervention for Emotional Distress After Traumatic Brain Injury. J Head Trauma Rehabil [Internet]. 2024; Available from: ["https://ezproxy.lib.ucalgary.ca/login?url=https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emexa&DO=10.1097%2fHTR.0000000000000945",
"https://ucalgary.primo.exlibrisgroup.com/openurl/01UCALG_INST/01UCALG_INST:UCALGARY?sid=OVID:embase&id=pmid:38833719&id=doi:10.1097%2FHTR.0000000000000945&issn=1550-509X&isbn=&volume=40&issue=1&spage=e13&pages=&date=2024&title=The+Journal+of+head+trauma+rehabilitation&atitle=Mood+Tracker%3A+A+Randomized+Controlled+Trial+of+a+Self-Monitoring+Intervention+for+Emotional+Distress+After+Traumatic+Brain+Injury&aulast=Sherer"]

24. Anthony CA, Peterson AR. Utilization of a text-messaging robot to assess intraday variation in concussion symptom severity scores. Clin J Sport Med Off J Can Acad Sport Med. 2015 Mar;25(2):149–52.

25. Forster SD, Gauggel S, Petershofer A, Völzke V, Mainz V. Ecological Momentary Assessment in Patients With an Acquired Brain Injury: A Pilot Study on Compliance and Fluctuations. Front Neurol. 2020 Mar 5;11:115.

26. Rabinowitz AR, Hart T. Adherence to high-frequency ecological momentary assessment in persons with moderate-to-severe traumatic brain injury. J Int Neuropsychol Soc. 2024 Oct;30(8):794–8.

27. Rabinowitz A, Hart T, Wilson J. Ecological momentary assessment of affect in context after traumatic brain injury. Rehabil Psychol. 2021 Nov;66(4):442–9.

28. Morrow EL, Mattis-Roesch H, Walsh K, Duff MC. Measurement of Sleep in Chronic Traumatic Brain Injury: Relationship Between Self-report and Actigraphy. J Head Trauma Rehabil. 2024;39(3):E132–40.

29. Karvandi E, Barrett L, Newcombe V, Hutchinson P, Helmy A. Digital health interventions for remote follow-up after mild traumatic brain injury. Br J Neurosurg. 2024;1–7.

30. Pellinen J., Sillau S., Morrison C., Maruff P., O'Brien T.J., Penovich P., et al. Engagement in online cognitive testing with the Cogstate brief battery among a multinational cohort of people with focal epilepsy. Epilepsy Behav. 2024;159:109953.

31. Lazeron-Savu E, Lenaert B, Dijkstra J, Ponds R, van Heugten C. Feasibility of a novel blended-care intervention for fatigue after acquired brain injury: a pilot study of the Tied by Tiredness intervention. Brain Inj. 2024;38(6):448–58.

32. Schultz LS, Murphy MA, Donegan M, Knights J, Baker JT, Thompson MF, et al. Evaluating the Acceptability and Feasibility of Collecting Passive Smartphone Data to Estimate Psychological Functioning in U.S. Service Members and Veterans: A Pilot Study. Mil Med. 2025 Jan 16;190(1–2):285–92.

33. Liu K, Madrigal E, Chung JS, Broffman JI, Bennett N, Tsai A, et al. Headache Diary Mobile Application for Monitoring and Characterizing Posttraumatic Headaches. J Head Trauma Rehabil. 2022 Jun 1;37(3):171–7.

34. Schoenfeld R, Drendel A, Ahamed SI, Thomas D. Longitudinal Assessment of Acute Concussion Outcomes Through SMS Text (ConText Study). Pediatr Emerg Care. 2022 Jan 1;38(1):e37–42.

35. Juengst SB, Graham KM, Pulantara IW, McCue M, Whyte EM, Dicianno BE, et al. Pilot feasibility of an mHealth system for conducting ecological momentary assessment of mood-

related symptoms following traumatic brain injury. Brain Inj. 2015;29(11):1351–61.

36. Juengst SB, Terhorst L, Kew CL, Wagner AK. Variability in daily self-reported emotional symptoms and fatigue measured over eight weeks in community dwelling individuals with traumatic brain injury. Brain Inj. 2019;33(5):567–73.

37. Llamas-Ramos R, Llamas-Ramos I, Pérez-Robledo F, Sánchez-González JL, Bermejo-Gil BM, Frutos-Bernal E, et al. Validity of the telematic Fugl Meyer assessment scale – upper extremity (TFMA-UE) Spanish version. Front Neurol. 2023 Aug 10;14:1226192.

38. Nabasny A, Rabinowitz A, Wright B, Wang J, Preminger S, Terhorst L, et al. Neurobehavioral Symptoms and Heart Rate Variability: Feasibility of Remote Collection Using Mobile Health Technology. J Head Trauma Rehabil. 2022 Jun 1;37(3):178–88.

39. Shelke S, Agu E. TBI2Vec: Traumatic Brain Injury Smartphone Sensing using AutoEncoder Embeddings. In: 2021 IEEE International Conference on Big Data (Big Data) [Internet]. Orlando, FL, USA: IEEE; 2021 [cited 2024 Dec 3]. p. 4770–9. Available from: https://ieeexplore.ieee.org/document/9671306/

40. Cruse N, Piotto V, Coelho C, Behn N. Telehealth administration of narrative and procedural discourse: A UK and US comparison of traumatic brain injury and matched controls. Int J Lang Commun Disord. 2024 Mar;59(2):519–31.

41. Cuthbert JP, Whiteneck GG, Corrigan JD, Bogner J. The Reliability of a Computer-Assisted Telephone Interview Version of the Ohio State University Traumatic Brain Injury Identification Method. J Head Trauma Rehabil. 2016 Jan;31(1):E36–42.

42. Gvozdanovic A, Jozsa F, Fersht N, Grover PJ, Kirby G, Kitchen N, et al. Integration of a personalised mobile health (mHealth) application into the care of patients with brain tumours: proof-of-concept study (IDEAL stage 1). BMJ Surg Interv Health Technol. 2022 Dec;4(1):e000130.

43. Rhea CK, Kuznetsov NA, Ross SE, Long B, Jakiela JT, Bailie JM, et al. Development of a Portable Tool for Screening Neuromotor Sequelae From Repetitive Low-Level Blast Exposure. Mil Med. 2017 Mar;182(S1):147–54.

44. Sufrinko AM, Howie EK, Charek DB, Elbin RJ, Collins MW, Kontos AP. Mobile Ecological

Momentary Assessment of Postconcussion Symptoms and Recovery Outcomes. J Head Trauma Rehabil. 2019 Nov;34(6):E40–8.

45. Rietdijk R, Power E, Brunner M, Togher L. Reliability of Videoconferencing Administration of a Communication Questionnaire to People With Traumatic Brain Injury and Their Close Others. J Head Trauma Rehabil. 2017;32(6):E38–44.

46. Martínez-Pernía D, Núñez-Huasaf J, Del Blanco Á, Ruiz-Tagle A, Velásquez J, Gomez M, et al. Using game authoring platforms to develop screen-based simulated functional assessments in persons with executive dysfunction following traumatic brain injury. J Biomed Inform. 2017 Oct;74:71–84.

47. Manor B, Zhou J, Lo OY, Zhu H, Gouskova NA, Yu W, et al. Self-Reported Head Trauma Predicts Poor Dual Task Gait in Retired National Football League Players. Ann Neurol. 2020 Jan;87(1):75–83.

48. Lee MJ, Gamaldo A, Peters ME, Roy D, Gamaldo CE, Sierra-Arce M, et al. Assessing Sleep Concerns in Individuals With Acquired Brain Injury: The Feasibility of a Smartpad Sleep Tool. J Neuropsychiatry Clin Neurosci. 2021;33(3):225–9.

49. Shaikh N, Theadom A, Siegert R, Hardaker N, King D, Hume P. Rasch analysis of the Brain Injury Screening Tool (BIST) in mild traumatic brain injury. BMC Neurol. 2021 Dec;21(1):376.

50. Morrow EL, Nelson LA, Duff MC, Mayberry LS. An Ecological Momentary Assessment and Intervention Tool for Memory in Chronic Traumatic Brain Injury: Development and Usability of Memory Ecological Momentary Intervention. JMIR Rehabil Assist Technol. 2024;11(101703412):e59630.

51. Sarker P, Hossain KF, Adhanom IB, Pavilionis PK, Murray NG, Tavakkoli A. Analysis of Smooth Pursuit Assessment in Virtual Reality and Concussion Detection using BiLSTM [Internet]. arXiv; 2022 [cited 2024 Dec 4]. Available from: https://arxiv.org/abs/2210.11238

52. Teel E, Gay M, Johnson B, Slobounov S. Determining sensitivity/specificity of virtual reality-based neuropsychological tool for detecting residual abnormalities following sport-related

concussion. Neuropsychology. 2016 May;30(4):474–83.

53. Canty AL, Fleming J, Patterson F, Green HJ, Man D, Shum DHK. Evaluation of a virtual reality prospective memory task for use with individuals with severe traumatic brain injury. Neuropsychol Rehabil. 2014;24(2):238–65.

54. Painter DR, Norwood MF, Marsh CH, Hine T, Harvie D, Libera M, et al. Immersive virtual reality gameplay detects visuospatial atypicality, including unilateral spatial neglect, following brain injury: a pilot study. J NeuroEngineering Rehabil. 2023 Nov 23;20(1):161.

55. Del Giovane M, Trender W, Bălăeț M, Mallas EJ, Jolly A, Bourke NJ, et al. Online Cognitive Assessment of Traumatic Brain Injury Patients is Accessible, Feasible and Performs Well Relative to Established Clinical [Internet]. SSRN; 2023 [cited 2024 Dec 3]. Available from: https://www.ssrn.com/abstract=4352554

56. Feigenbaum LA, Kim KJ, Gaunaurd IA, Kaplan LD, Scavo VA, Bennett C, et al. POST-CONCUSSIVE CHANGES IN BALANCE AND POSTURAL STABILITY MEASURED WITH CANESENSE™ AND THE BALANCE ERROR SCORING SYSTEM (BESS) IN DIVISION I COLLEGIATE FOOTBALL PLAYERS: A CASE SERIES. Int J Sports Phys Ther. 2019 Apr;14(2):296–307.

57. Huber DL, Thomas DG, Danduran M, Meier TB, McCrea MA, Nelson LD. Quantifying Activity Levels After Sport-Related Concussion Using Actigraph and Mobile (mHealth) Technologies. J Athl Train. 2019 Sep;54(9):929–38.

58. Wen PS, Mackey J, Rose D, Waid-Ebbs JK. Smartphone Application for Measuring Community Participation in Veterans With Traumatic Brain Injury. OTJR Occup Ther J Res. 2021 Jul;41(3):196–205.

59. Juengst SB, Wright B, Sander AM, Preminger S, Nabasny A, Terhorst L. The Behavioral Assessment Screening Tool for Mobile Health (BASTmHealth): Development and Compliance in 2 Weeks of Daily Reporting in Chronic Traumatic Brain Injury. Arch Phys Med Rehabil. 2023 Feb;104(2):203–10.

60. Dummar MK, Crowell MS, Pitt W, Yu AM, McHenry P, Benedict T, et al. The Convergent Validity of the SWAY Balance Application to Assess Postural Stability in Military Cadets

Recovering from Concussion. Int J Sports Phys Ther. 2024;19(2):166–75.

61. Seton C, Coutrot A, Hornberger M, Spiers HJ, Knight R, Whyatt C. Wayfinding and path integration deficits detected using a virtual reality mobile app in patients with traumatic brain injury. Cristofori I, editor. PLOS ONE. 2023 Mar 9;18(3):e0282255.

62. Schatz P, Sandel N. Sensitivity and specificity of the online version of ImPACT in high school and collegiate athletes. Am J Sports Med. 2013 Feb;41(2):321–6.

63. Mendez-Lopez M., Juan M.-C., Burgos T., Mendez M., Fidalgo C. AO - Fidalgo CO https://orcid.org/0000-0002-4732-6417. How people with brain injury run and evaluate a SLAM-based smartphone augmented reality application to assess object-location memory. PsyCh J. 2024;13(6):903 EP – 914.

64. VanNostrand M, Rieger B, Baracks J, Neville C. Development and initial validation of a digital divided-attention neurocognitive test for use in concussion assessment. Brain Inj. 2019 Jun 7;33(7):941–51.

65. Robitaille N, Jackson PL, Hébert LJ, Mercier C, Bouyer LJ, Fecteau S, et al. A Virtual Reality avatar interaction (VRai) platform to assess residual executive dysfunction in active military personnel with previous mild traumatic brain injury: proof of concept. Disabil Rehabil Assist Technol. 2017 Oct;12(7):758–64.

66. Goverover Y, DeLuca J. Actual reality: Using the Internet to assess everyday functioning after traumatic brain injury. Brain Inj. 2015;29(6):715–21.

67. S Okahashi, H Mizumoto, K Ueno, M Yokoyama, Nagano A, K Seki, et al. Assessment of convalescent brain-damaged patients using a virtual shopping test with different task difficulties. In Japan; 2014.

68. Wong AWK, Heinemann AW, Miskovic A, Semik P, Snyder TM. Feasibility of Computerized Adaptive Testing for Collection of Patient-Reported Outcomes After Inpatient Rehabilitation. Arch Phys Med Rehabil. 2014 May;95(5):882–91.

69. McGrath LB, Eaton J, Abecassis IJ, Maxin A, Kelly C, Chesnut RM, et al. Mobile Smartphone-Based Digital Pupillometry Curves in the Diagnosis of Traumatic Brain Injury. Front Neurosci. 2022;16:893711.

70. Rhea CK, Yamada M, Kuznetsov NA, Jakiela JT, LoJacono CT, Ross SE, et al. Neuromotor changes in participants with a concussion history can be detected with a custom smartphone app. PloS One. 2022;17(12):e0278994.

71. Yadav N, Poellabauer C, Daudet L, Collins T, McQuillan S, Flynn P. Portable neurological disease assessment using temporal analysis of speech. In: Proceedings of the 6th ACM Conference on Bioinformatics, Computational Biology and Health Informatics [Internet]. Atlanta Georgia: ACM; 2015 [cited 2024 Dec 4]. p. 77–85. Available from: https://dl.acm.org/doi/10.1145/2808719.2808727

72. Kis M. Reliability of a New Test of Balance Function in Healthy and Concussion Populations. J Funct Morphol Kinesiol. 2020 Feb 14;5(1):13.

73. Schatz P, Sandel N. Sensitivity and specificity of the online version of ImPACT in high school and collegiate athletes. Am J Sports Med. 2013 Feb;41(2):321–6.

74. Tirosh O., Klonis J., Hamilton M., Olver J., Wickramasinghe N., Mckenzie D., et al. Smartphone Technology to Facilitate Remote Postural Balance Assessment in Acute Concussion Management: Pilot Study. Sensors [Internet]. 2024;24(21). Available from: ["https://ezproxy.lib.ucalgary.ca/login?url=https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emexb&DO=10.3390%2fs24216870", "https://ucalgary.primo.exlibrisgroup.com/openurl/01UCALG_INST/01UCALG_INST:UCALGARY?sid=OVID:embase&id=pmid:39517769&id=doi:10.3390%2Fs24216870&issn=1424-8220&isbn=&volume=24&issue=21&spage=&pages=&date=2024&title=Sensors+%28Basel%2C+Switzerland%29&atitle=Smartphone+Technology+to+Facilitate+Remote+Postural+Balance+Assessment+in+Acute+Concussion+Management%3A+Pilot+Study&aulast=Tirosh"]

75. Rice V, Boykin G, Alfred P, Lindsay G, Overby C, Jeter A, et al. The investigation of four technologies to assist in detecting mild to moderate traumatic brain injury of U.S. Military service members. Work Read Mass. 2019;63(2):165–80.

76. Spreij LA, Gosselt IK, Visser-Meily JMA, Hoogerbrugge AJ, Kootstra TM, Nijboer TCW. The journey is just as important as the destination-Digital neuropsychological assessment provides performance stability measures in patients with acquired brain injury. PloS One.

2021;16(7):e0249886.

77. Dutta P. Utility of iPhone-Based Pupillometry in Comparing Pupillary Dynamics Between Sport Concussed Subjects With Photosensitivity and Healthy Controls. J Neuro-Ophthalmol Off J North Am Neuro-Ophthalmol Soc. 2024;44(3):371–5.

78. Turkstra LS, Quinn-Padron M, Johnson JE, Workinger MS, Antoniotti N. In-Person Versus Telehealth Assessment of Discourse Ability in Adults With Traumatic Brain Injury. J Head Trauma Rehabil. 2012 Nov;27(6):424–32.

79. Vargas BB, Shepard M, Hentz JG, Kutyreff C, Hershey LG, Starling AJ. Feasibility and accuracy of teleconcussion for acute evaluation of suspected concussion. Neurology. 2017 Apr 18;88(16):1580–3.

80. Wallace SE, Donoso Brown EV, Schreiber JB, Diehl S, Kinney J, Zangara L. Touchscreen tablet-based cognitive assessment versus paper-based assessments for traumatic brain injury. NeuroRehabilitation. 2019;45(1):25–36.

81. Shukla D, Thombre BD, Baby P, Palaninathan J, Subramanian S, Prathyusha P, et al. Validity of Glasgow outcome scale-extended (GOSE) mobile application for assessment of outcome in traumatic brain injury patients. Brain Inj. 2023 Aug 24;37(10):1215–9.

82. Lumetta K, Halama S, Fehr S, Apps J, Thomas D. Functional Assessment of Concussion Tool Application in a Pediatric Concussion Clinic. WMJ Off Publ State Med Soc Wis. 2023 Jul;122(3):191–5.

83. Zapata-Soria M, Muñoz-Vigueras N, Cabrera-Martos I, López-López L, Ortiz-Rubio A, Valenza MC. Agreement between telerehabilitation and face-to-face orofacial myofunctional assessment in persons with acquired brain injury. Brain Inj. 2023 Jul 3;37(8):669–74.

84. Chen PM, Lee S, Cruz LD, Lopez M, Thomas A, Chen JW, et al. iPad-Based Neurocognitive Testing (ImPACT-QT) in Acute Adult Mild Traumatic Brain Injury/Concussion: Study on Practicality and Bedside Cognitive Scores in a Level-1 Trauma Center. Am Surg. 2024;90(6):1570–6.

85. Falcone M, Yadav N, Poellabauer C, Flynn P. Using isolated vowel sounds for classification of Mild Traumatic Brain Injury. In: 2013 IEEE International Conference on Acoustics, Speech

and Signal Processing [Internet]. Vancouver, BC, Canada: IEEE; 2013 [cited 2024 Dec 3]. p. 7577–81. Available from: http://ieeexplore.ieee.org/document/6639136/

86. Teel EF, Slobounov SM. Validation of a virtual reality balance module for use in clinical concussion assessment and management. Clin J Sport Med Off J Can Acad Sport Med. 2015 Mar;25(2):144–8.

87. Fischer TD, Red SD, Chuang AZ, Jones EB, McCarthy JJ, Patel SS, et al. Detection of Subtle Cognitive Changes after mTBI Using a Novel Tablet-Based Task. J Neurotrauma. 2016 Jul 1;33(13):1237–46.

88. Yang S, Flores B, Magal R, Harris K, Gross J, Ewbank A, et al. Diagnostic accuracy of tablet-based software for the detection of concussion. Kobeissy FH, editor. PLOS ONE. 2017 Jul 7;12(7):e0179352.

89. Wilkerson GB, Acocello SN, Davis MB, Ramos JM, Rucker AJ, Hogg JA. Wellness Survey Responses and Smartphone App Response Efficiency: Associations With Remote History of Sport-Related Concussion. Percept Mot Skills. 2021 Apr;128(2):714–30.

90. Gardner RC, Rivera E, O'Grady M, Doherty C, Yaffe K, Corrigan JD, et al. Screening for Lifetime History of Traumatic Brain Injury Among Older American and Irish Adults at Risk for Dementia: Development and Validation of a Web-Based Survey. J Alzheimers Dis JAD. 2020;74(2):699–711.

91. Schultebraucks K, Yadav V, Galatzer-Levy IR. Utilization of Machine Learning-Based Computer Vision and Voice Analysis to Derive Digital Biomarkers of Cognitive Functioning in Trauma Survivors. Digit Biomark. 2020 Dec 30;5(1):16–23.

92. Shen J, Koterba C, Samora J, Leonard J, Li R, Shi J, et al. Usability and validity of a virtual reality cognitive assessment tool for pediatric traumatic brain injury. Rehabil Psychol. 2022 Nov;67(4):587–96.

93. Nadler Tzadok Y, Eliav R, Portnoy S, Rand D. Establishing the Validity of the Internet-Based Bill-Paying Task to Assess Executive Function Deficits Among Adults With Traumatic Brain Injury. Am J Occup Ther Off Publ Am Occup Ther Assoc. 2022 Jul 1;76(4):7604205110.

94. Mobbs A., Kahn M., Williams G., Mentiplay B.F., Pua Y.-H., Clark R.A. Machine learning for

automating subjective clinical assessment of gait impairment in people with acquired brain injury - a comparison of an image extraction and classification system to expert scoring. J NeuroEngineering Rehabil. 2024;21(1):124.

95. Sullivan K.A., Caltabiano E. AO - Sullivan KAO https://orcid.org/0000-0002-5952-5114. Online screening assessment of lifetime exposure to traumatic brain injury: a pilot study of associations between exposure and health status. Brain Impair. 2024;25(1):IB23080.

96. Lencses A, Mikula B, Mioni G, Rendell PG, Denes Z, Demeter G. Prospective memory functions in traumatic brain injury: The role of neuropsychological deficits, metamemory and impaired self-awareness. J Neuropsychol [Internet]. 2024;(101468753). Available from: ["https://ezproxy.lib.ucalgary.ca/login?url=https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medp&DO=10.1111%2fjnp.12388", "https://ucalgary.primo.exlibrisgroup.com/openurl/01UCALG_INST/01UCALG_INST:UCALGARY?sid=OVID:medline&id=pmid:39188167&id=doi:10.1111%2Fjnp.12388&issn=1748-6645&isbn=&volume=&issue=&spage=&pages=&date=2024&title=Journal+of+Neuropsychology&atitle=Prospective+memory+functions+in+traumatic+brain+injury%3A+The+role+of+neuropsychological+deficits%2C+metamemory+and+impaired+self-awareness.&aulast=Lencses"]

97. Malegiannaki AC, Garefalaki E, Pellas N, Kosmidis MH. Virtual Reality Assessment of Attention Deficits in Traumatic Brain Injury: Effectiveness and Ecological Validity. Multimodal Technol Interact. 2024 Jan 3;8(1):3.

98. Lequerica A., Arango-Lasprilla J.C., Corrigan J. Preliminary validation of a checklist for lifetime exposure to sources of central nervous system compromise. Arch Phys Med Rehabil. 2024;105(4):e113.

99. Maxin AJ, Gulek BG, Lee C, Lim D, Mariakakis A, Levitt MR, et al. Validation of a Smartphone Pupillometry Application in Diagnosing Severe Traumatic Brain Injury. J Neurotrauma. 2023 Oct;40(19–20):2118–25.

100. Spreij LA, Gosselt IK, Visser-Meily JMA, Nijboer TCW. Digital neuropsychological assessment: Feasibility and applicability in patients with acquired brain injury. J Clin Exp Neuropsychol. 2020 Sep 13;42(8):781–93.

101. Caze Ii T, Knell GP, Abt J, Burkhart SO. Management and Treatment of Concussions via Tele-Concussion in a Pediatric Setting: Methodological Approach and Descriptive Analysis. JMIR Pediatr Parent. 2020 Aug 13;3(2):e19924.

102. Ellis MJ, Boles S, Derksen V, Dawyduk B, Amadu A, Stelmack K, et al. Evaluation of a pilot paediatric concussion telemedicine programme for northern communities in Manitoba. Int J Circumpolar Health. 2019 Jan 1;78(1):1573163.

103. Marckmann C, John D. Telemedicine, Quality Initiative for Concussion Management. J Nurse Pract. 2020 Jan;16(1):e9–12.

104. Ezekiel L, Wilding H, Dearling J, Collett J, Dawes H. Exploring the usefulness of real-time digitally supported fatigue monitoring in fatigue management: Perspectives from occupational therapists and brain injury survivors. Br J Occup Ther. 2024;87(12):783–92.

105. Rebchuk AD, Alimohammadi A, Yuan M, Cairncross M, Torres IJ, Silverberg ND, et al. Assessment of Prorated Scoring of an Abbreviated Protocol for the National Institutes of Health Toolbox Cognition Battery. J Int Neuropsychol Soc JINS. 2020 Nov;26(10):1045–50.

106. Carrick FR, Azzolino SF, Hunfalvay M, Pagnacco G, Oggero E, D'Arcy RCN, et al. The Pupillary Light Reflex as a Biomarker of Concussion. Life Basel Switz. 2021 Oct 18;11(10):1104.

107. Lequerica AH, Lucca C, Chiaravalloti ND, Ward I, Corrigan JD. Feasibility and Preliminary Validation of an Online Version of the Ohio State University Traumatic Brain Injury Identification Method. Arch Phys Med Rehabil. 2018 Sep;99(9):1811–7.

108. Sullan MJ, Kinney AR, Stearns-Yoder KA, Reis DJ, Saldyt EG, Forster JE, et al. A randomized clinical trial for a self-guided sleep intervention following moderate-severe traumatic brain injury: Study protocol. Contemp Clin Trials. 2024;141(101242342):107525.

109. Ezekiel L, Veiga JJD, Ward T, Dawes H, Collett J. Exploring the usability of a smartphone application to monitor fatigue and activity for people with acquired brain injury. Br J Occup Ther. 2023 Nov;86(11):767–76.

110. Juengst SB, Terhorst L, Kew CL, Wagner AK. Variability in daily self-reported emotional

symptoms and fatigue measured over eight weeks in community dwelling individuals with traumatic brain injury. Brain Inj. 2019 Apr 16;33(5):567–73.

111. Rhea CK, Yamada M, Kuznetsov NA, Jakiela JT, LoJacono CT, Ross SE, et al. Neuromotor changes in participants with a concussion history can be detected with a custom smartphone app. Roemmich RT, editor. PLOS ONE. 2022 Dec 15;17(12):e0278994.

112. Feigenbaum LA, Kim KJ, Gaunaurd IA, Kaplan LD, Scavo VA, Bennett C, et al. POST-CONCUSSIVE CHANGES IN BALANCE AND POSTURAL STABILITY MEASURED WITH CANESENSE™ AND THE BALANCE ERROR SCORING SYSTEM (BESS) IN DIVISION I COLLEGIATE FOOTBALL PLAYERS: A CASE SERIES. Int J Sports Phys Ther. 2019 Apr;14(2):296–307.

113. Maxin AJ, Gulek BG, Lee C, Lim D, Mariakakis A, Levitt MR, et al. Validation of a Smartphone Pupillometry Application in Diagnosing Severe Traumatic Brain Injury. J Neurotrauma. 2023 Oct 1;40(19–20):2118–25.

114. Shiffman S, Stone AA, Hufford MR. Ecological Momentary Assessment. Annu Rev Clin Psychol. 2008 Apr 1;4(1):1–32.

115. Cuthbert JP, Whiteneck GG, Corrigan JD, Bogner J. The Reliability of a Computer-Assisted Telephone Interview Version of the Ohio State University Traumatic Brain Injury Identification Method. J Head Trauma Rehabil. 2016;31(1):E36-42.

116. Maxin A.J., Gulek B.G., Lee C., Lim D., Mariakakis A., Levitt M.R., et al. Response to Zanier and Citerio, Evaluating a Pupillometry App Considering Sedation's Impact: A Step Unexplored (DOI: 10.1089/neu.2023.0431). J Neurotrauma. 2024;41(1):296 EP – 297.

117. Dunn KL, Bay RC, Cárdenas JF, Anastasi M, Valovich McLeod TC, Williams RM. Reliability of the Sway Balance Mobile Application: A Retrospective Analysis. Int J Athl Ther Train. 2018 Mar;23(2):69–72.

118. Zapata-Soria M, Muñoz-Vigueras N, Cabrera-Martos I, López-López L, Ortiz-Rubio A, Valenza MC. Agreement between telerehabilitation and face-to-face orofacial myofunctional assessment in persons with acquired brain injury. Brain Inj. 2023 Jul 3;37(8):669–74.

119. Wong AWK, Heinemann AW, Miskovic A, Semik P, Snyder TM. Feasibility of computerized

adaptive testing for collection of patient-reported outcomes after inpatient rehabilitation. Arch Phys Med Rehabil. 2014 May;95(5):882–91.

120. Shukla D, Thombre BD, Baby P, Palaninathan J, Subramanian S, Prathyusha PV, et al. Validity of Glasgow outcome scale-extended (GOSE) mobile application for assessment of outcome in traumatic brain injury patients. Brain Inj. 2023 Aug 24;37(10):1215–9.

121. Nabasny A, Rabinowitz A, Wright B, Wang J, Preminger S, Terhorst L, et al. Neurobehavioral Symptoms and Heart Rate Variability: Feasibility of Remote Collection Using Mobile Health Technology. J Head Trauma Rehabil. 2022 Jun 1;37(3):178–88.

122. Juengst SB, Wright B, Sander AM, Preminger S, Nabasny A, Terhorst L. The Behavioral Assessment Screening Tool for Mobile Health (BASTmHealth): Development and Compliance in 2 Weeks of Daily Reporting in Chronic Traumatic Brain Injury. Arch Phys Med Rehabil. 2023 Feb;104(2):203–10.

123. Rabinowitz A.R., Hart T. AO - Hart TO https://orcid. org/0000 0003 2716 3929 AR .. Adherence to high-frequency ecological momentary assessment in persons with moderate-to-severe traumatic brain injury. J Int Neuropsychol Soc JINS. 2024;30(8):794 EP – 798.

124. Martínez-Pernía D, Núñez-Huasaf J, Del Blanco Á, Ruiz-Tagle A, Velásquez J, Gomez M, et al. Using game authoring platforms to develop screen-based simulated functional assessments in persons with executive dysfunction following traumatic brain injury. J Biomed Inform. 2017 Oct;74:71–84.

125. Seton C, Coutrot A, Hornberger M, Spiers HJ, Knight R, Whyatt C. Wayfinding and path integration deficits detected using a virtual reality mobile app in patients with traumatic brain injury. PloS One. 2023;18(3):e0282255.

126. Turkstra LS, Quinn-Padron M, Johnson JE, Workinger MS, Antoniotti N. In-Person Versus Telehealth Assessment of Discourse Ability in Adults With Traumatic Brain Injury. J Head Trauma Rehabil. 2012 Nov;27(6):424–32.

127. Rietdijk R, Power E, Brunner M, Togher L. The reliability of evaluating conversations between people with traumatic brain injury and their communication partners via videoconferencing. Neuropsychol Rehabil. 2020 Jul;30(6):1074–91.

128. Ellis MJ, Boles S, Derksen V, Dawyduk B, Amadu A, Stelmack K, et al. Evaluation of a pilot paediatric concussion telemedicine programme for northern communities in Manitoba. Int J Circumpolar Health. 2019 Dec;78(1):1573163.

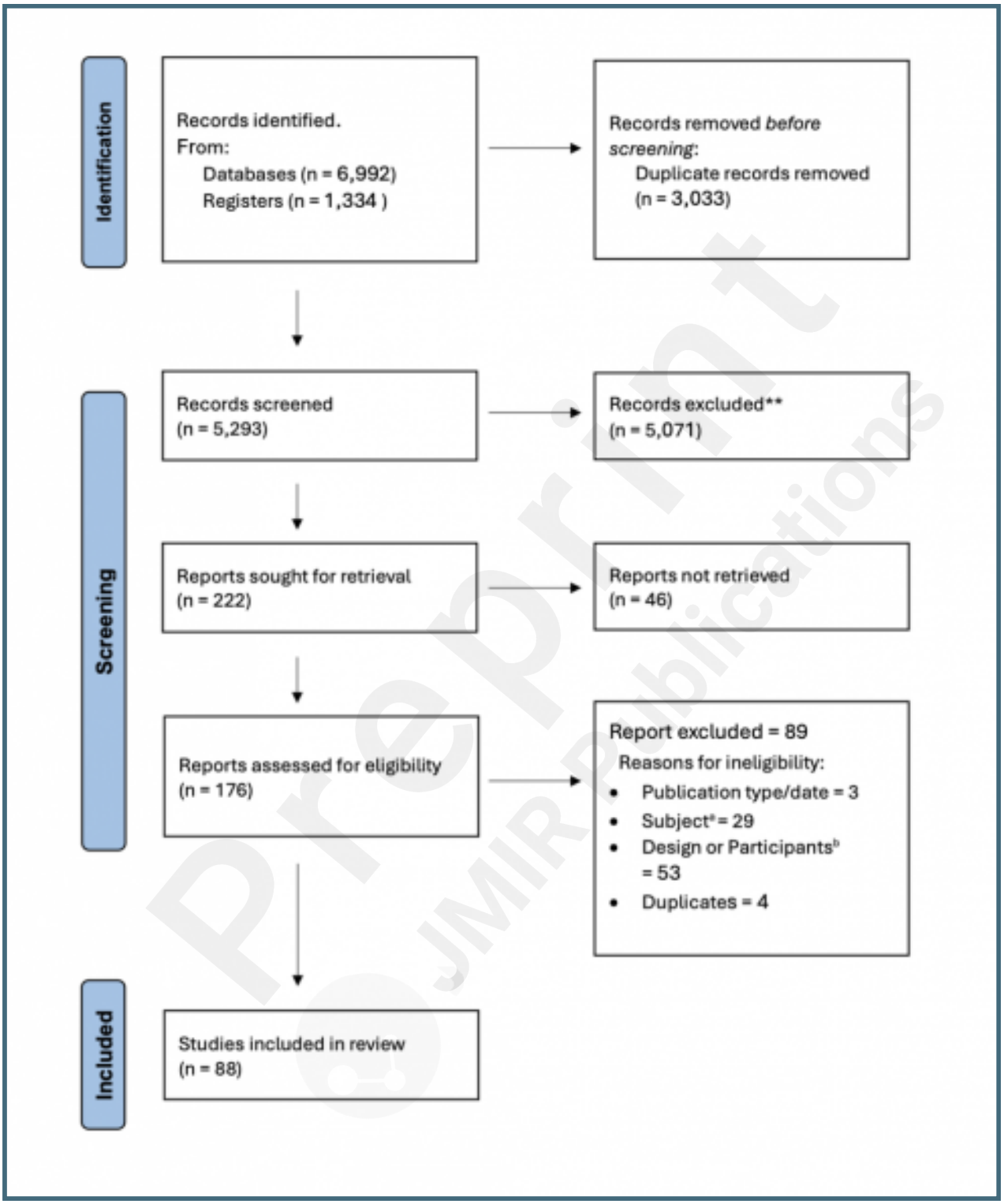
Supplementary Files

Untitled.
URL: http://asset.jmir.pub/assets/cc144ab2845d54ec2f6dce51c4ec6342.docx

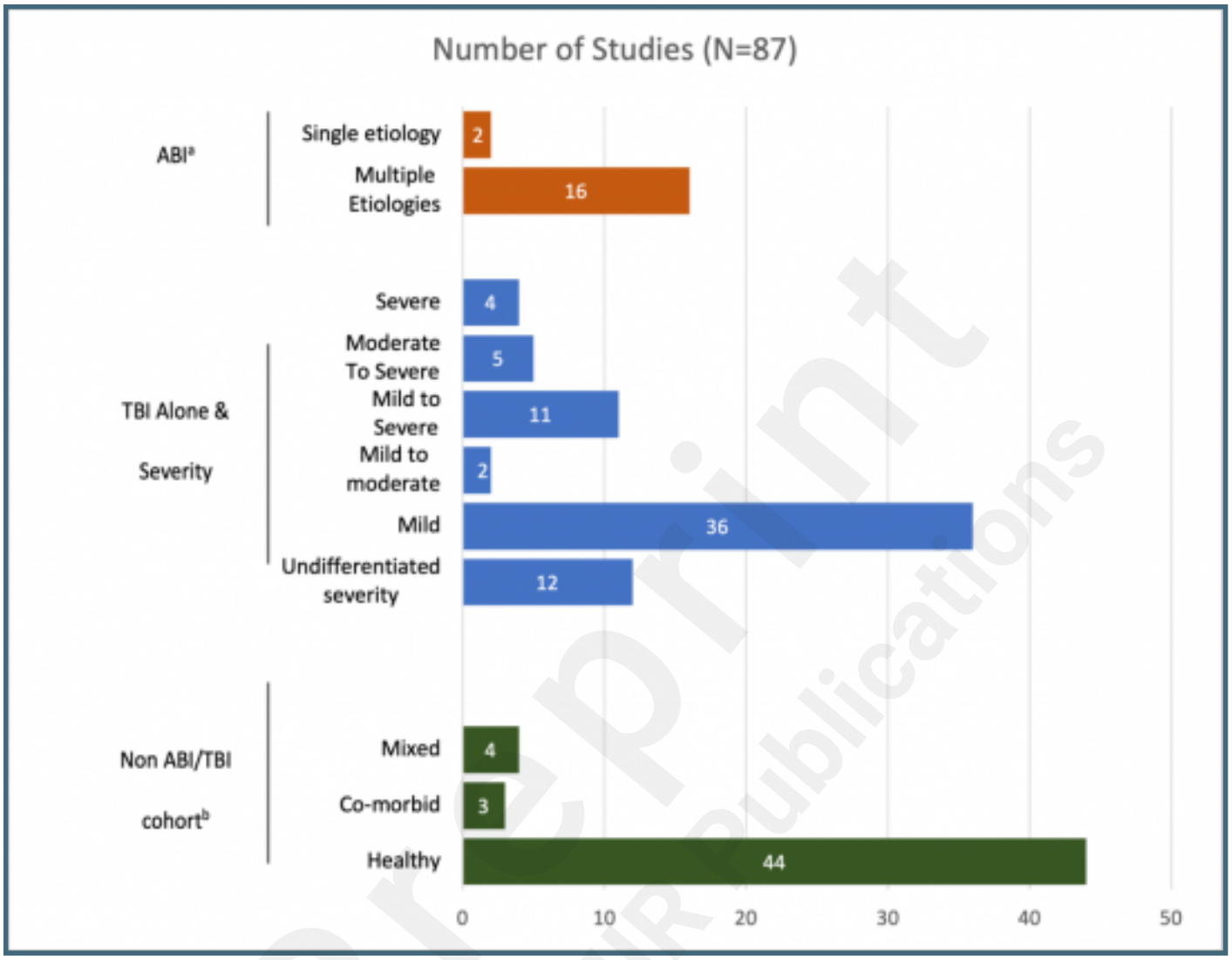
Untitled.
URL: http://asset.jmir.pub/assets/90acabc553ec60e527d05d0944be0e5f.pdf

Figures

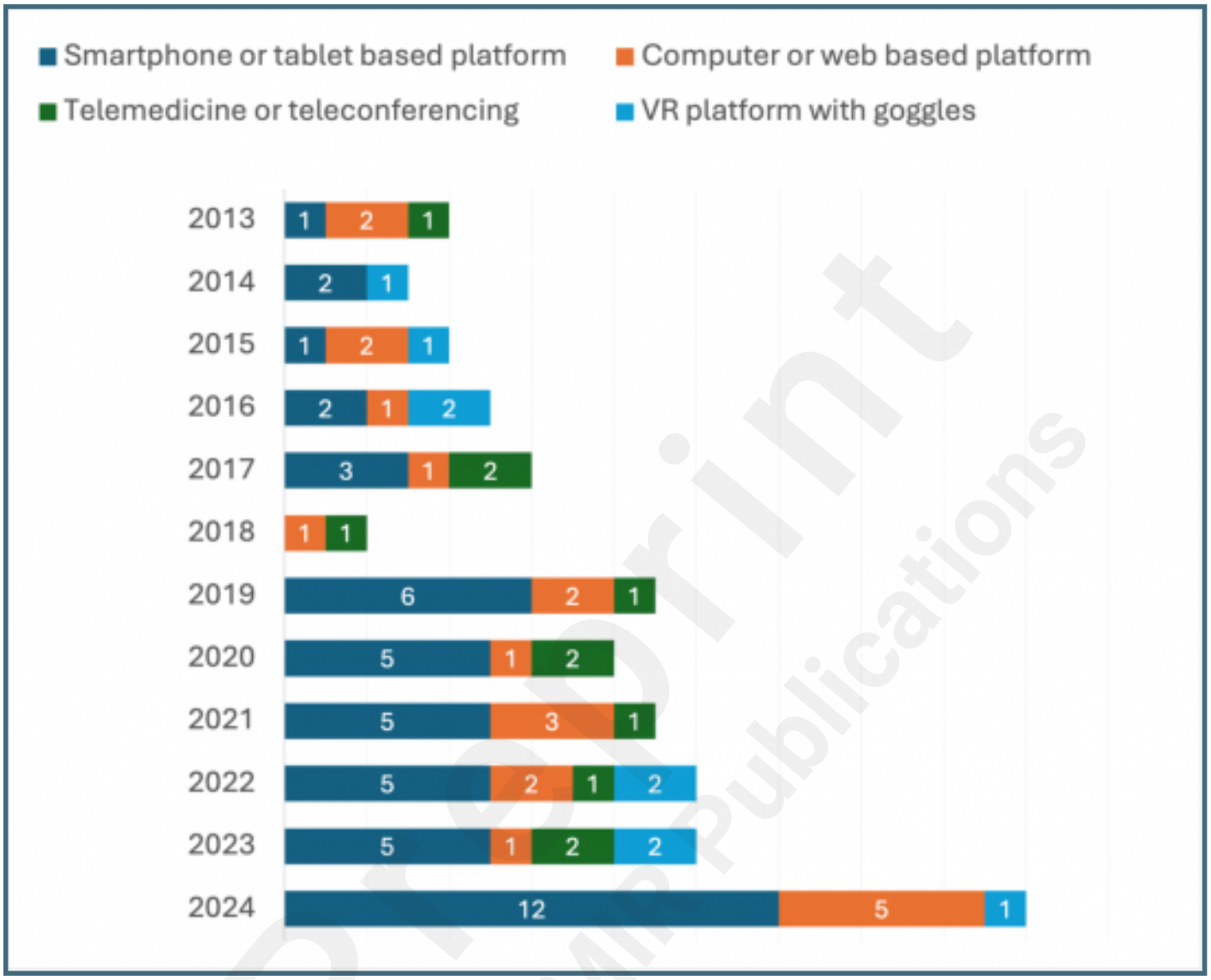
PRISMA-SCr flowchart outlining the results from the review and selection process.



Characteristics of Participants: Etiology of ABI, TBI Severity and non-ABI cohort.



Trends in technology platforms studied over time.



Multimedia Appendixes

Supplementary Table and Abbreviations.
URL: http://asset.jmir.pub/assets/9b6cedee1be90e464a16a57110e63343.docx

Definitions and search criteria.
URL: http://asset.jmir.pub/assets/338f0fd050b905c437be9267f906f9ce.docx

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-scr) Checklist.
URL: http://asset.jmir.pub/assets/085aad94bbb5a38a292d821832d3df29.docx