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Review

Clinical measures of balance in people with type two diabetes: A systematic literature review

C.J. Dixon[a], T. Knight[b], E. Binns[c], B. Ihaka[d], D. O'Brien[c,*]

[a] Torbay Physiotherapy and Hand Therapy, 1042 Beach Road, Torbay, Auckland, New Zealand
[b] Taranaki Base Hospital, David Street, New Plymouth 4310, New Zealand
[c] Physiotherapy Department, School of Clinical Sciences, Faculty of Health and Environmental Sciences, Auckland University of Technology, Auckland, New Zealand
[d] Podiatry Department, School of Clinical Sciences, Faculty of Health and Environmental Sciences, Auckland University of Technology, Auckland, New Zealand

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ABSTRACT

Approximately 422 million people have diabetes mellitus worldwide, with the majority diagnosed with type 2 diabetes mellitus (T2DM). The complications of diabetes mellitus include diabetic peripheral neuropathy (DPN) and retinopathy, both of which can lead to balance impairments. Balance assessment is therefore an integral component of the clinical assessment of a person with T2DM. Although there are a variety of balance measures available, it is uncertain which measures are the most appropriate for this population. Therefore, the aim of this study was to conduct a systematic review on clinical balance measures used with people with T2DM and DPN.

Databases searched included: CINAHL plus, MEDLINE, SPORTDiscus, Dentistry and Oral Sciences source, and SCOPUS. Key terms, inclusion and exclusion criteria were used to identify appropriate studies. Identified studies were critiqued using the Downs and Black appraisal tool.

Eight studies were included, these studies incorporated a total of ten different clinical balance measures. The balance measures identified included the Dynamic Balance Test, balance walk, tandem and unipedal stance, Functional Reach Test, Clinical Test of Sensory Interaction and Balance, Berg Balance Scale, Tinetti Performance-Oriented Mobility Assessment, Activity-Specific Balance Confidence Scale, Timed Up and Go test, and the Dynamic Gait Index.

Numerous clinical balance measures were used for people with T2DM. However, the identified balance measures did not assess all of the systems of balance, and most had not been validated in a T2DM population. Therefore, future research is needed to identify the validity of a balance measure that assesses these systems in people with T2DM.

1. Introduction

Diabetes mellitus (DM) is a chronic metabolic condition that affects the body's ability to regulate blood glucose levels [1]. DM is a key health issue, with an increase in the prevalence of Type 2 DM (T2DM), directly linked to lifestyle factors [2]. Older adults with T2DM have a high prevalence for falls and the commonly identified risk factor is poor balance [3]. Balance is the maintenance or restoration of a person's centre of mass within their limits of stability [4]. A variety of balance control systems (reactive, anticipatory, sensory, dynamic, and limits of stability) and physiological systems (vestibular, visual, proprioceptive, muscle strength, and reaction time) contribute to the maintenance of balance [4]. It requires cognitive processing and integration of multiple physiological systems, so that an appropriately timed and scaled output is performed to maintain postural control [5]. Balance is a dynamic process and the weighting of an input shifts according to the task for example, when walking in the dark inputs from the somatosensory and vestibular systems are weighted more than visual. Therefore, a deficit in one system increases the demand on inputs from the other systems and can lead to impaired balance. T2DM can often cause changes that affect the somatosensory, vestibular and visual systems [6,7]. Prolonged hyperglycaemia which occurs with T2DM stimulates a raft of metabolic

Abbreviations: ABC, activities specific balance confidence scale; BBS, Berg balance scale; BESTest, balance evaluation systems test; CASP, critical appraisal skills programme; CTSIB, clinical test of sensory interaction and balance; DGI, Dynamic Gait Index; DM, diabetes mellitus; DPN, diabetic peripheral neuropathy; FRT, functional reach test; NDC, non diabetic controls; POMA, Tinetti performance oriented mobility scale; T2DM, type II diabetes mellitus; TUG, timed up and go test

* Corresponding author at: Physiotherapy Department, School of Clinical Sciences, Faculty of Health and Environmental Sciences, Auckland University of Technology, Auckland, New Zealand.

E-mail addresses: christinajdixon7@gmail.com (C.J. Dixon), tuiknight@live.com (T. Knight), lbinns@aut.ac.nz (E. Binns), bihaka@aut.ac.nz (B. Ihaka), daniel.obrien@aut.ac.nz, dobrien@aut.ac.nz (D. O'Brien).

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interactions. This can cause endoneural hypoxia altering nerve perfusion particularly to glucose dependent tissue including peripheral nerves (resulting in diabetic peripheral neuropathy [DPN]), the retina (resulting in diabetic retinopathy) and the vestibular system [3,8]. DPN can alter movement perception as a result of diminished proprioceptive and cutaneous input from the skin, muscles and joints. Diabetic retinopathy can affect the sensory receptors in the retina responsible for providing visual information of the surrounding environment and orientation of the body [9]. Diminished sensitivity in the vestibular system can alter perception regarding motion, equilibrium, and spatial orientation necessary to maintain posture [3]. Additionally, prolonged hyperglycaemia can also lead to muscle weakness, joint stiffness and early degenerative changes in the brain [8,10]. These are all factors that may further impair balance control in people with T2DM.

Impaired balance is one of the top three risk factors for falling, and therefore associated with fear of falling, and reduced quality of life in people with T2DM [11,12]. T2DM is also identified as an independent risk factor for falls in older adults [13,14]. Balance is assessed to identify fall risk, the kind of balance disorder or the underlying physiological impairment contributing to the balance disorder, and to inform treatment choices. Treatments can then be targeted to the balance disorder at a functional level to reduce the impact of the impairment and facilitate function (such as virtual reality techniques, lifestyle modification and the removal of home hazards) or at a physiological level to improve a sensorimotor system (such as balance and strength retraining or vestibular rehabilitation [3,15–17]). Although there are many valid clinical measures for assessing balance in the healthy population, the validity of these measures for use with people with T2DM is unclear [6,12]. In the context of this study, validity is defined as the statistical certainty that a balance measure measures what it is said to measure and can be further defined as face, content, construct or criterion [18]. Therefore, the aim of this study was to conduct a systematic review of clinical balance measures in people with T2DM and DPN.

2. Methods

2.1. Search strategy

A comprehensive search of the following electronic databases was completed on 29 March 2015: CINAHL plus, MEDLINE, SPORTDiscus, Dentistry and Oral Sciences source, and SCOPUS. Search terms used were extrapolated from the key terms in the study question and included: Diabetes, balance, validity and outcome measure (Table 1). Search terms were combined with 'AND'.

The titles of all of the identified articles were screened independently by two members of the research team (CD and TK). Articles were retained if the title referred to the clinical assessment of balance in people with T2DM and/or DPN. Duplicates of articles were discarded. The abstracts of all retained articles were reviewed. If the abstract did not relate to the clinical assessment of balance in people with T2DM, the article was discarded. The full text of all remaining articles were read by two members of the research team (CD and TK), and reviewed for suitability using the following inclusion and exclusion criteria. The reference lists of the selected articles were screened for further studies that would merit inclusion in this systematic review.

Table 1
Search terms.

Diabetes search terms combined with "OR"
(diabet* N5 2)
(diabet* N5 "II")
(diabet* N5 neuropathy)
Balance search terms combined with "OR"
balance
fall*
postur*
Validity search terms combined with "OR"
valid*
reliab*
psychometric
Outcome measure search terms combined with "OR"
Tool
Test
Measure
Questionnaire
Outcome
Index
Scale

2.2. Inclusion and exclusion criteria

Articles were included if they were written in English, used a clinical measure of either balance or postural stability or fall risk, had participants with T2DM or diabetes with DPN, and had full text available. Articles were excluded if they only assessed gait or fall risk, were not published in a peer reviewed journal, or only used measures which required specialist equipment that may not be available to all clinicians working with people with T2DM (i.e. Biodex Stability System or force-platform).

2.3. Study quality appraisal and data extraction

All studies were critiqued using the Downs and Black critical appraisal tool [19]. This tool includes 27 items, a 'Yes' response is allocated a '1' and a 'No' response is allocated a 0, therefore studies are rated out of a total of 27 points. In instances where a question did not apply to the methodology of a particular study, it was rated as not applicable (NA). The response of 'NA' was rated as 0 and was included in the total rating so that each paper remained rated out of a total of 27. The item and total Downs and Black scores for each paper was recorded.

In addition to the appraisal of quality, all retained studies were subjected to the following data extraction process. The study design, participant characteristics, control group characteristics and interventions of each study were identified. The balance measures used in each study were also identified and validation of these measures was noted. An answer of 'Yes' indicated that the study had validated the measures it used and 'No' where they had not. The main findings of each of the studies were then summarised. Furthermore, a list of the balance measures used across all of the studies was collated and the balance system assessed by each measure were identified.

3. Results

3.1. Study selection

A total of 105 studies were identified during the literature search. A further 22 studies were identified by reviewing the reference list of articles retained and reviewed in full text version. One hundred and seven studies were removed after reading the abstracts as they did not contain the key concepts of the study question. The majority of these studies were excluded either (i) because they focused on assessing fall risk, (ii) employed specialist equipment not typically found in a clinic or (iii) included participants with a variety of different illnesses meaning that the results were not exclusive to people with T2DM or diabetes with DPN. Twenty studies were believed to contain the key concepts of the study question, of these a further 12 studies were excluded. Eleven because they used specialised technology and one additional study because it only utilised fall risk measures (Fig. 1). Therefore, a total of eight studies were retained for the critical appraisal and data extraction.

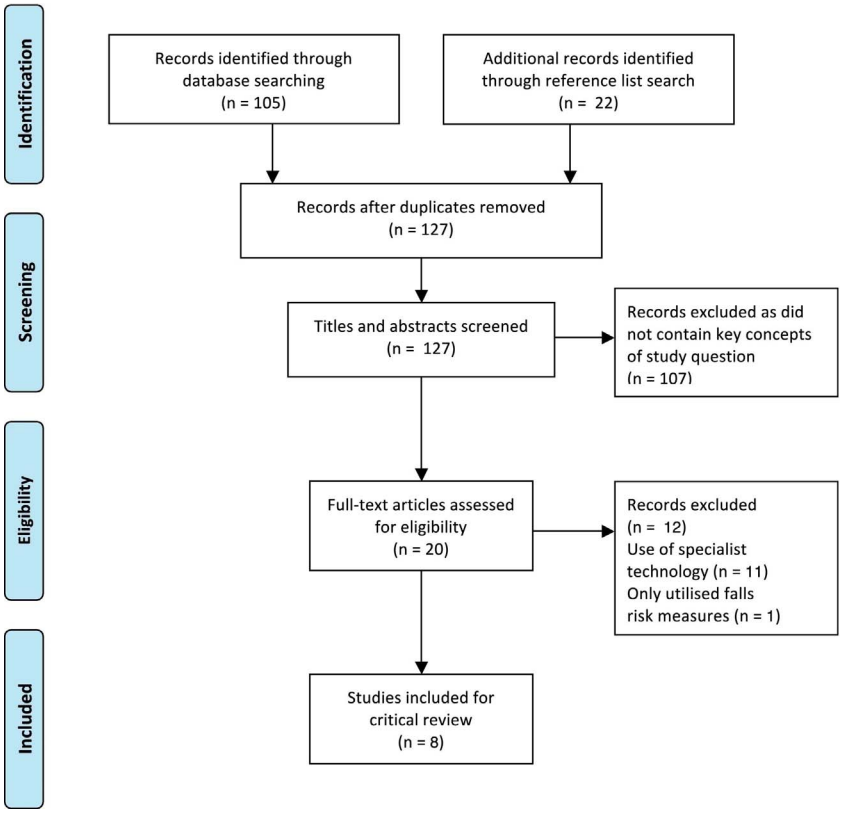

Fig. 1. Study selection process.

3.2. Methodological quality

The Downs and Black scores ranged between 8 and 19/27 (Table 2). As shown in Table 2, most of the reviewed studies rated poorly on external validity, as the recruitment methods and study location were not clearly described. Furthermore, it was unclear whether participants were representative of the general diabetes population, as many of the studies did not compare study group characteristics to those of the general population. Studies also scored poorly on the rating of validity and reliability of the outcome measures used, as these were not well described in most of the studies. The intervention studies did not include blinding and did not describe participant compliance with the intervention.

Overall, studies rated well for clear reporting methods and had a moderate rating of bias. Many studies scored poorly for confounding and external validity. However, three questions (questions 4, 14 and 19) were not rated as applicable to non-interventional studies and a further three questions (9, 17 and 26) were not applicable to the studies that employed a cross-sectional study design because there was no follow-up. Furthermore, seven of the studies were unable to randomise participants to groups, so a further two questions were not applicable (question 23 and 24).

3.3. Extracted data

Study characteristics data were extracted from the eight studies (Table 2). Additionally, data were extracted about the use and validation of balance measures.

3.3.1. Study design

Four of the eight studies employed a cross-sectional design [7,12,20,21], one was a case control study [22], two were non-randomised controlled interventional studies [23,24], and one was a prospective randomised controlled clinical trial [25].

3.3.2. Participants

Study participant ages ranged from 40 to 80 years old. Four of the eight studies included participants with T2DM [7,20,21,25], while six of the studies included participants with DPN [7,12,20–22,24].

3.3.3. Balance measures

From the eight studies reviewed, 10 different balance measures were identified. A summary of these balance measures and the balance systems they assess are presented in Table 4. Several of the balance assessment measures were used in multiple studies; these included the Berg Balance Scale (BBS), Timed Up and Go (TUG), Functional Reach Test (FRT), Tinetti Performance Oriented Mobility Assessment (POMA) and tandem and unipedal stance. The TUG was the measure most commonly used to assess balance, appearing in four different studies [12,21,23], followed by the BBS and POMA. Several measures [Dynamic Gait Index (DGI), dynamic balance test, balance walk,and Activities Specific Balance Confidence scale (ABC)] were only utilised once in the identified studies [20,21,24,25]. Two of these measures, the dynamic balance test and balance walk, were not validated and appeared to be created by the authors [20,25]. Most of the 10 balance measures identified focused on the assessment of reactive and anticipatory balance, limits of stability, dynamic stability and sensory integration (Table 4).

3.3.4. Validation of outcome measures

Several studies described the relevance of the clinical balance measures included in their study. However, few studies indicated or demonstrated that the measures were known to be valid for use with people with T2DM. Vaz et al. [21] stated that the BBS and TUG show good inter- and intra-rater reliability, whilst Jernigan et al. [12] stated that the TUG, BBS, FRT and DGI were chosen as they were easy to use in a clinical setting and measured either static or dynamic balance. The DGI was chosen because it alters sensory systems that may be relied upon in people with DPN. Jernigan et al. [12] further stated that TUG, BBS and FRT were all measures known to be validated in an older

Table 2
Summary of Downs and Black scores for individual items.

Question	Allet et al. 2010 [25]	Richardson et al. 2001 [24]	Vaz et al. 2013 [21]	Cimbiz & Cakir 2005 [22]	Resnick et al. 2002 [20]	Corriveau et al. 2000 [7]	Jernigan et al. 2012 [12]	Najafi et al. 2013 [23]
1. Is the hypothesis/aim/objective clearly described?	1	1	1	1	1	1	1	1
2. Are the main outcomes to be measured clearly described in the introduction or methods section?	1	1	1	1	1	1	1	1
3. Are the characteristics of the patients included in the study clearly described?	1	1	1	1	1	1	1	0
4. Are the interventions of the interest clearly described?	1	1	NA	NA	NA	NA	NA	NA
5. Are the distributions of the principal confounders in each group of subjects to be compared clearly described?	1	1	1	1	1	1	NA	0
6. Are the main findings of the study clearly described?	1	1	1	1	1	1	1	1
7. Does the study provide estimates of the random variability in the data for the main outcomes?	1	1	1	1	1	1	1	1
8. Have all the important adverse events that may be a consequence of the intervention been reported?	1	1	0	0	0	0	0	0
9. Have the characteristics of patients lost to follow-up been described?	1	1	NA	NA	NA	NA	NA	NA
10. Have actual probability values been reported for the main outcomes except where the probability value is less than 0.001?	1	1	0	0	0	1	0	1
11. Were the subjects asked to participate in the study representative of the entire population from which they were recruited?	0	0	0	0	0	0	0	0
12. Were the subjects who were prepared to participate representative of the entire population from which they were recruited?	0	0	0	0	0	0	0	0
13. Were the staff, places and facilities where the patients were treated representative of the treatment the majority of patients received?	1	0	0	0	0	0	0	0
14. Was an attempt made to blind study subjects to the intervention they received?	0	0	NA	NA	NA	NA	NA	0
15. Was an attempt made to blind those measuring the main outcomes of the intervention?	0	0	0	0	0	NA	NA	0
16. If any of the results of the study were based on “data dredging” was this made clear?	1	1	1	1	1	1	1	1
17. In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for case and controls?	1	1	NA	NA	NA	NA	NA	NA
18. Were the statistical tests used to assess the main outcomes appropriate?	1	1	1	1	1	1	1	1
19. Was compliance with the intervention/s reliable?	0	0	NA	NA	NA	NA	NA	NA
20. Were the main outcome measures used accurate (valid and reliable)?	0	0	1	0	0	0	1	0
21. Were the patients in different intervention groups or were the cases and controls recruited from the same population?	1	0	1	0	0	0	NA	1
22. Were the study subjects in different interventions groups or were the cases and controls recruited over the same period of time?	0	0	0	0	0	0	0	0
23. Were study subjects randomised into intervention groups?	1	0	NA	0	NA	NA	NA	NA
24. Was the randomised intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?	0	0	NA	0	NA	NA	NA	NA
25. Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?	1	0	0	1	1	0	1	0
26. Were losses of patients to follow-up taken into account?	1	0	NA	NA	NA	NA	NA	NA
27. Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?	1	0	1	1	1	1	1	0
Total	19	13	11	10	10	10	10	8

Table 3
Summary of studies included in review.

Study	Downs & Black score (/27)	Study design	Participants	Intervention	Interventional control group	Balance measures	Main findings	Valid measures
Allet et al. 2010 [25]	19	Prospective RCT.	Adults (mean age 63 ± 7.99) with T2DM (n = 71).	Physiotherapeutic group circuit training including gait and balance exercises with function-orientated strengthening. 2 times per week for 12 weeks. 60 min per session. (n = 35)	No treatment or advice. Able to continue with usual activities. (n = 36)	-POMA -Dynamic balance test	Intervention group participants significantly improved their POMA score and dynamic balance compared to the control group.	No
Richardson, et al. 2001 [24]	13	Controlled trial.	Adults 50–80 years with DPN (n = 20) divided evenly into control and intervention groups.	Daily exercises for 3 weeks. Range of motion, toe and heel raises (bipedal and unipedal), inversion and eversion (bipedal and unipedal), wall slides and unipedal balance. (n = 10)	Control exercise regimen (upper limb strengthening and neck range of motion). 5–7x/week for 3 weeks. (n = 10)	-Tandem stance -Unipedal stance -FRT -ABC	Intervention subjects demonstrated significant improvements in all three balance measures ($p < 0.05$) but no significant difference in the ABC Scale ($p = 0.64$).	No
Vaz et al. 2013 [21]	11	Cross-sectional.	Adults aged 40–65 years with T2DM and DPN (n = 19), matched group with T2DM, without DPN (n = 13) and NDC (n = 30).	No intervention.		-TUG -BBS	T2DM groups performed significantly better on the TUG and BBS than the NDC group ($p < 0.05$).	No
Cimbiz & Cakir 2005 [22]	10	Case controlled.	Adults with DPN (n = 30) mean age 57.5 ± 3.9 and matched NDC (n = 30) mean age 55.6 ± 6.1.	No intervention.		-Unipedal stance -FRT	The DPN group performed significantly worse on the static and dynamic one leg stand test and functional reach than the NDC group.	No
Resnick et al. 2002 [20]	10	Cross-sectional.	Older adults aged 70–79 years with T2DM and DPN (n = 14), matched group with T2DM, without DPN (n = 13) and NDC (n = 12).	No intervention.		-Tadem stand -Unipedal stand -Balance walk	For tandem and unipedal stands and balance walk T2DM groups scored worse than control ($p < 0.05$). No differences between T2DM groups and NDC group for balance walk.	No
Corriveau et al. 2000 [7]	10	Cross-sectional.	Older (mean age 68.8 ± 5.5) with T2DM and DPN (n = 15) and NDC (n = 15).	No intervention.		-POMA	Significantly different group scores for the POMA between DPN patients and NDC subjects ($p = 0.002$).	No
Jernigan, et al. 2012 [12]	10	Cross-sectional.	Adults aged 40–65yrs with DPN (n = 36). Divided into two groups based on falls history; recurrent fallers (n = 10) and non-fallers (n = 26).	No intervention.		-Falls history (to classify as recurrent fallers − ≥2 falls- or non-fallers − ≤1 fall) -FRT -TUG -BBS -DGI	Traditional cut-off scores: DGI showed the highest overall accuracy. Modified cut-off scores: all tools showed better sensitivity and the TUG showed the highest accuracy.	Yes
Najafi, et al. 2013 [23]	8	Controlled trial.	Older adults over 65 years with DPN (n = 8). Divided evenly into two groups based on falls risk assessed using POMA.	No intervention.		-TUG -POMA	Mean TUG scores were significantly higher for high risk of falling group ($p = 0.028$). TUG scores showed excellent correlation with POMA scores.	No

Note. Studies ordered by Downs and Black score. RCT = randomised controlled trial, T2DM = type II diabetes mellitus, DM = diabetes mellitus, DPN = diabetic peripheral neuropathy, NDC = non-diabetic controls, FRT = functional reach test, ABC = activities specific balance confidence scale, CTSIB = clinical test of sensory interaction and balance, TUG = timed up and go, BBS = Berg balance scale, DGI = Dynamic Gait Index, POMA = Tinetti performance-oriented mobility assessment.

Table 4
Summary of balance assessment measures.

Balance assessment measures	*Description of the measure*	*Physiological or balance system assessed*
Dynamic balance test [25]	A person is timed walking as fast and as precisely as possible on a 5 m beam (15 cm high, 15 cm wide).	Reactive and anticipatory balance, limits of stability.
Balance walk [20]	A person is timed walking a 6m × 20 cm course at their usual pace. A deviation is stepping on, or going outside the path marked on the floor (scored only if there were no more than two deviations from the path).	Dynamic stability.
Tandem and unipedal stance [20,22,24]	A person stands with one foot in front of the other (heel to toe), then on one leg with: eyes open (60 s), eyes closed (30 s), and eyes open, with head rotation (30 s) with arms held comfortably at the side. Tests are recorded as achieved or not.	Anticipatory balance, limits of stability, sensory integration of vestibular and somatosensory systems.
Functional reach test (FRT) [12,22,24]	A person stands facing along a wall, with their arm raised to 90°, their hand in a fist. They reach forward as far as possible without taking a step. The distance between the start and end position of the third metacarpal is measured and reported as the reach distance.	Limits of stability.
Berg balance scale (BBS) [12,21]	A person performs 14 physical tasks increasing in balance difficulty from sitting to standing on one leg. Each task is scored from 0 to 4, 4 being able to complete the task.	Anticipatory balance and reactive balance, limits of stability, sensory integration of the visual, vestibular and somatosensory system, dynamic stability.
Tinetti performance-oriented mobility assessment (POMA) [7,23,25]	A person performs 16 (9 balance tasks scored out of 16 and 7 gait tasks scored out of 12) tasks scored subjectively from 0 to 1 or 0–2.	Anticipatory balance and reactive balance when challenged, sensory integration of the visual, vestibular and somatosensory system, limits of stability, dynamic stability.
Activity specific balance confidence scale (ABC) [24]	Self-report questionnaire of 16-items rating balance confidence when performing everyday activities. “How confident are you that you will not lose your balance or become unsteady when you…”. Each item is rated 0–100%. Overall score is the average for all items rated and is a percentage.	Confidence performing specific activities without falling or becoming unsteady.
Timed up and go (TUG) [12,21,23]	A person sits in a chair with arms. On “go”, they stand, walk 3 m at a comfortable and safe pace, turn, walks back to the chair and sits down. Timing begins at “go” and stops when the person is seated.	Dynamic stability.
Dynamic Gait Index (DGI) [12]	A person walks 20 feet 7 times, each time completing a different task: normal walking, walking with changing speeds, walking with head turns (both horizontally and vertically), a pivot turn, walking stepping over and walking around obstacles, and going up stairs. Each task is scored 0–3, with 3 the highest level of function.	Anticipatory balance, sensory integration of the visual and somatosensory systems, dynamic stability.

population. Additionally, some of the identified measures were reported to be validated in people with Parkinson’s disease, stroke and vestibular disorders [26–28].

Of the eight studies in this review, only one study attempted to validate the balance assessment measures used, but this was done in the context of fall risk [12]. The aim of this study was to determine a measure which could accurately distinguish between non-fallers and potential fallers who had underlying DPN. Traditional and modified cut-off scores were compared to determine the sensitivity, specificity and positive and negative likelihood ratios of the BBS, FRT, DGI and TUG. Traditional cut-off scores were based on those established by the original developers of the measures or identified in literature whilst the modified cut off scores were calculated using receiver operating characteristic curves. The DGI showed the best overall specificity and sensitivity based on traditional cut off scores, whilst the TUG performed best with the modified scores. All measures showed improved sensitivity and marginally reduced specificity with modified cut-off scores (Table 3).

4. Discussion

There are two key findings from this systematic review. Firstly, a wide range of different clinical balance measures were used to assess balance in people with T2DM. Secondly, the methodological quality of the included studies varied considerably when rated by the Downs and Black critical appraisal tool. Beyond these key findings, a few points merit further discussion. The findings indicate that very few of the clinical balance measures used in the identified studies have been validated for people with T2DM. Additionally, none of the validated balance measures appear to explore all the systems of balance. Finally, a number of the measures described as balance measures, such as the TUG and FRT, are not exclusively clinical balance measures. These measures are better described as measures of functional performance or functional mobility. One study attempted to validate the four balance measures (FRT, BBS, DGI and TUG), which were selected for their ease of use in the clinical setting and their validation in the older adult population [12]. However, the validation of these clinical balance measures were only in relation to fall risk and not the specific sensory deficit. As such, these measures could be suitable for a T2DM population to assess fall risk rather than as a measure of sensory deficit.

None of the identified clinical balance measures in this review assessed all of the different aspects of balance and nor were any shown to be valid measures of balance for use with people with T2DM. However, two of the identified clinical balance measures (BBS and POMA) may merit use with this population. The BBS and POMA challenges the somatosensory and visual systems. Although, the BBS and POMA may be influenced by ceiling effects in people with T2DM [4].

The findings of this review indicate a number of the studies used functional performance measures as clinical measures of balance. Two measures of functional performance that are commonly used to assess balance are the FRT and TUG. The FRT, although designed to measure limits of stability, correlates poorly with centre of mass displacement due to the wide variety of compensatory strategies an individual can utilise to complete this task [4]. The TUG was designed to assess functional performance, while the measure does challenge a number of the systems associated with balance, it is not a measure of balance [29]. Pain, muscle weakness and joint stiffness in the lower limbs can all limit TUG performance, but are not necessarily directly related to balance. Therefore, neither measure is a valid measure of balance.

4.1. Recommendations for future research and clinical practice

This systematic literature review identified that while there are currently many different clinical measures used to assess balance in people with T2DM, but none of these measures explore all of the components of balance. Furthermore, while some measures have been

validated for assessing fall risk, none of the measures have been validated for assessing the balance of people with T2DM. Therefore, there is a need to validate an appropriate multi-systems measure for the assessment of balance in people with T2DM.

Healthcare practitioners measuring the balance of their patients with T2DM could do so by either, performing a battery of different tests that cover all of the systems of balance, or by utilising a single measure that assesses all of these systems. One such test is the Balance Evaluation Systems Test (BESTest), which is a newer balance measure and was not used by any of the studies in this review [30]. This multi-system measure combines items from other clinical balance assessment measures and is described as assessing the following six balance systems: biomechanical constraints, limits of stability, anticipatory postural adjustment, postural responses, sensory orientation and dynamic stability. This balance measure has been tested with people with peripheral neuropathy, multiple sclerosis, acute stroke and Parkinson's disease; and has good inter and intra-rater reliability [30–33]. Therefore, future research could explore the validity and reliability of this balance measure in the T2DM population.

4.2. Strengths and limitations

The strengths of this study include the robust critical process undertaken in this review and the focus on clinical balance assessment measures that can be used in any clinic setting, making it very applicable to clinical practice. The main limitation of this review was the selection of the critical appraisal tool. The Downs and Black appraisal tool was designed to critique quantitative interventional studies. Most of the identified studies were non-interventional resulting in some questions being deemed not applicable. This limitation was only appreciated on completion of the review. Future systematic reviews may benefit from using a critiquing tool that is receptive to different study designs, such as the Critical Appraisal Skills Programme (CASP) checklist [34].

5. Conclusions

This critical review identified eight studies and 10 different clinical measures of balance used with people with T2DM. Many of the different systems of balance were assessed by the measures used in these studies. However, no single validated measure was identified that assessed all of these systems. Therefore, further research is required that explores the reliability and validity of multi-factorial balance measures for people with T2DM.

Ethics approval and consent to participate

Not applicable.

Consent to publication

Not applicable.

Availability of data and materials

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Authors contributions

CD and TK completed the literature search and analysis and drafted the manuscript. DOB, BI and EB conceived the study, participated in its design and coordination, and helped draft and edit the manuscript. All authors read and approved the final manuscript.

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