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An Updated Systematic Review of Turnout Position Assessment Protocols Used in Dance Medicine and Science Research

Manuela Angioi, PhD, Karis Hodgson, BMBS, BSc, and Katrine Okholm Kryger, PhD

Abstract

Turnout, or external rotation of the lower limbs, is an integral part of classical ballet technique. Contributions of lower limb structures to turnout can be separated into HER (hip external rotation) and NHCTO (non-hip contributions to turnout). This study aimed to review systematically methods used to measure turnout in dance medicine and science research, thereby updating the literature since the Champion and Chatfield review of 2008. CINAHL, EMBASE, PubMed, and Web of Science were searched in January 2018 by two independent reviewers. Peer-reviewed studies measuring turnout in dance were included, except those published prior to March 23, 2006, as that was the last date of publication included in the previous review. Abstracts, theses, and editorials were excluded. From each study, study design, population (sample size, sex, age, genre of dance, and level of training), details of the protocol used, and result of turnout measurement were extracted, as well as reliability data. All included studies were assessed for risk of bias, using either Newcastle-Ottawa scale, AXIS tool, or PEDro scale as appropriate for each study design. A total of 41 studies met the inclusion criteria. Twenty-eight studies measured HER, nine measured NCHTO, and 22 measured total turnout (TTO). An increased number of studies investigated TTO (N = 22; N = 4 passive TTO) and NHCTO (N = 9) since 2006. All studies scored above half the points attainable from their respective tools. Results suggest HER remains the most common protocol for measuring turnout (N = 28), despite the fact it disregards input from structures below the hip. It is concluded that researchers should focus on quality of reporting of protocols to ensure repeatability and facilitate comparison of results. Future studies should include absolute reliability and validity testing of all currently used protocols so that standardization can be fully achieved.

Turnout is an integral component of classical dance technique which involves external rotation of the lower limb.[1] In *The Code of Terpischore*, a fundamental textbook of dance that carefully describes dance positions, training, and performance, Carlo Blasis insisted on "feet turned completely outwards in a straight line"[2] as the desired position of turnout. Dancers trained by Blasis went on to perform in Saint Petersburg, Paris, and London, which spread the influence of his style, contributing to the foundation of ballet and dance as we know it today.[3] With the evolution of dance, there are inconsistencies in the way turnout has come to be defined among researchers. Some stipulate Blasis' traditional "ideal" form of turnout where the lower limb is externally rotated such that the feet lie at 180°, with external rotation occurring principally at the hip.[4-7] Others acknowledge contributions of structures below the hip, defining turnout as the sum of hip external rotation (HER), knee rotation, tibial torsion, and toe valgus.[8-11] Alternative definitions include full external rotation of the hips and lower limbs within the constraints of bony anatomy, ligament flexibility, and muscular strength and control. The latter definition is arguably the most comprehensive, as it acknowledges the variety of strategies used by dancers to achieve turnout.[4,12] For the purposes of this review, turnout has been divided into three different elements: hip external rotation (HER), non-hip contributions to turnout (NHCTO), and total turnout (TTO). Non-hip contributions to turnout refers to all contributions to turnout below the hip, including degree of femoral version, tibial torsion, and rotation occurring at the knee, ankle, and foot. Total turnout is the degree of turnout as measured at the feet, in

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theory including all contributors to the measurement.

In 2008, Champion and Chatfield[13] published a review reporting on the variability of protocols used to measure turnout in dance research. Due to multiple procedures and lack of a gold-standard protocol, they were unable to produce normative data, instead providing recommendations to improve standardization of the measurement[13] (Fig. 1). These recommendations are particularly important when assessing individual strategies employed by dancers to achieve maximal turnout measured at the feet (Fig. 2). For example, Quanbeck et al.[8] reported a contribution of 32% by the knee to TTO in a sample of 10 pre-professional and professional dancers.

In dance research, it is acknowledged that "ideal" turnout technique should involve external rotation primarily from the hips, and that poor technique (i.e., excessive external rotation from lower limb structures) can contribute to the risk of injury. However, the lack of standardization has prevented results to this effect from being compared and thereby reinforced.[14,15] Van Merkensteijn and Quin[15] found that the difference between the degree of overall turnout reached by female university-level modern dancers and the degree of passive hip external rotation available to them (compensated turnout) was significantly related to their injury risk, particularly traumatic injury. However, their study included a sample of only 22 dancers and did not take into account tibial torsion, an anatomical feature that contributes to turnout through external rotation between the proximal and distal tibia.[15]

Intrinsic and extrinsic components are believed to contribute to inter-individual variations. Potential anatomical contributing factors include acetabular depth and femoral version, which influence when the neck of the femur will contact the acetabulum, hence limiting HER.[13] In addition, tibial torsion (normal external rotation of the tibia) and flexibility of ligaments and joint capsules may impact turnout (Fig. 3). Training factors are also thought to alter the

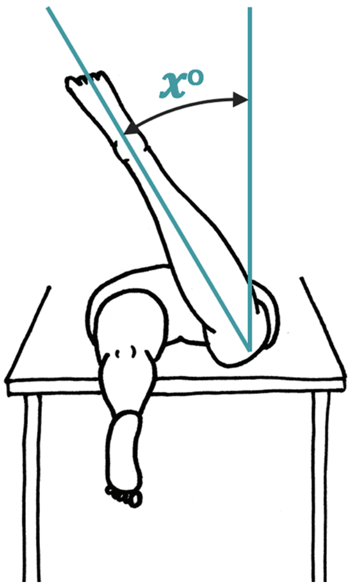

Figure 1 Measurement of HER in the prone position as recommended by Champion and Chatfield.[13]

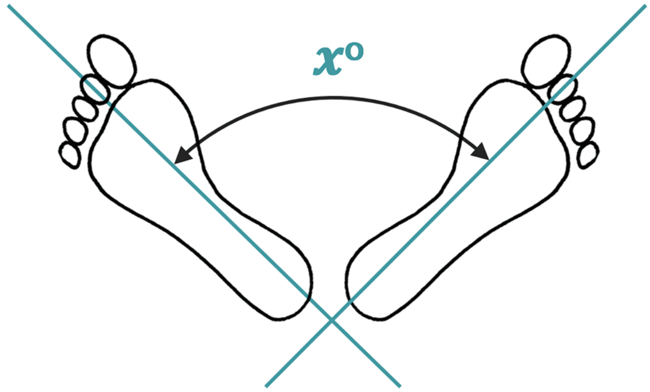

Figure 2 Schematic demonstrating total turnout at the feet (TTO) and the axis of the foot through which TTO angle is measured.

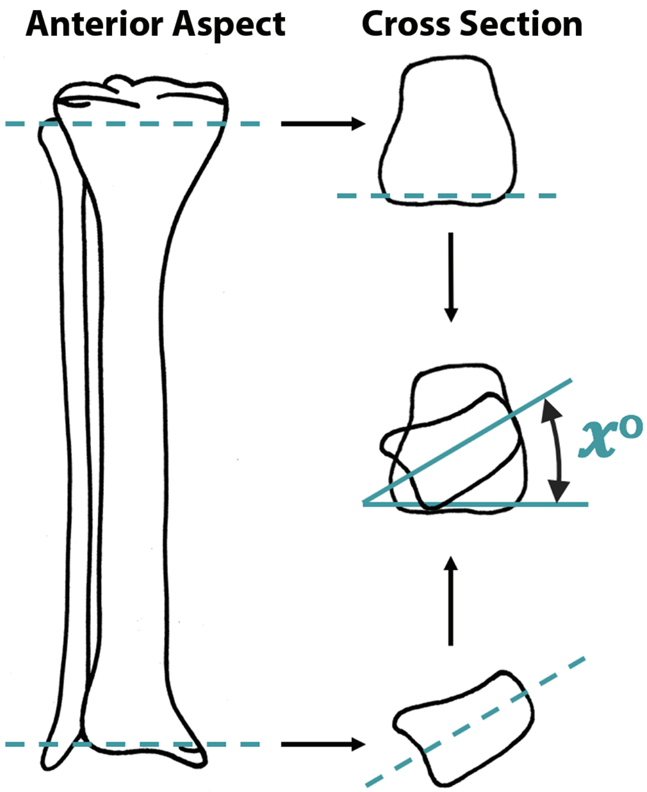

Figure 3 Tibial torsion, demonstrated here as the difference in angle between the cross section of the proximal and distal tibia.

turnout available to dancers. Iunes et al.[6] found a significant difference between the total turnout angle achieved by dancers when compared with age matched controls, presumably the result of their training. Sutton-Triana et al.[10] found that ballet dancers had increased strength in external rotation as compared with non-dancers, which correlates with increased HER. Those authors also reported that ballet dancers had significantly less femoral version than non-dancers, suggesting that sustained ballet training might lead to change in bone morphology.[10] As anatomical variations are likely to alter how a dancer achieves turnout, an ideal measurement protocol should include these factors.

Since Champion and Chatfield[13] published their review in 2008, dance medicine and science research has evolved and new methods of measuring turnout have been used, such as the kinematic analysis of Quanbeck et al.[8] The present review aims to describe the methods currently used to measure turnout, thereby updating the literature included in the Champion and Chatfield review. In the future this may contribute to a standardized measure such that normative values of turnout can be developed.

Methods

The PRISMA statement was consulted prior to the start of this review and the checklist completed.[16]

Eligibility criteria

As this review aims to update that of Champion and Chatfield, the start date was set at March 23, 2006, the publication date of the latest paper included in the earlier review. Inclusion and exclusion criteria used in selecting studies are described in Table 1.

Search Strategy

A comprehensive literature search was carried out on the following databases: CINAHL, EMBASE, PubMed, and Web of Science. Search terms for the two themes of turnout and dance are detailed in Table 2. In line with the PRISMA guidelines, an example of the electronic search strategy used in one database has been included and is shown in Table 3. Terms used for each database were identical, with no limitations placed on the search. MeSH terms were used for "dance"; however, as MeSH terms did not exist for turn-

Table 1 Eligibility Criteria Used to Select Studies for Review

Inclusion criteria	Exclusion criteria
Published since March 23, 2006	Published in language other than English
Turnout measured in a dance population	Unpublished or conference proceedings
Peer reviewed original research	Studies on aesthetic athletes other than dancers (e.g., gymnasts or figure skaters).
	Flexibility measures other than turnout in dance population
	Insufficient detail of methodology to determine measurement protocol used

Table 2 Terms Used in the Literature Search

Theme	Search terms
Turnout	turnout OR first position OR hip external rotation OR hip range of motion OR lower extremity external rotation OR lower limb external rotation
Dance	dance OR dancer* OR dancing OR ballet

Note: Themes were combined with AND; *= truncation symbol also referred to as a "wildcard."

Table 3 Electronic Search Strategy Conducted on PubMed

The title was split into two key concepts: Turnout and Dance Research. Concept searches were combined with AND. No MeSH terms were found for "turnout"

MeSH Terms: Dance = Dance, Ballet, Square Dance, Dance, Square, Hip-Hop Dance, Dance, Hip-Hop, Hip Hop Dance, Jazz Dance, Dance, Jazz, Tap Dance, Dance, Tap, Modern Dance, Dance, Modern, Salsa Dancing, Dancing, Salsa, Line Dancing, Dancing, Line

Concept 1 Search Terms: Turnout OR non-hip components of turnout OR tibial version OR total turnout OR first position OR hip external rotation OR hip range of motion OR hip joint flexibility OR hip passive range of motion OR active hip external rotation OR passive hip external rotation OR active external rotation lag OR foot progression angle OR below hip external rotation OR non-hip external rotation OR lower limb external rotation OR thigh-foot angle

Concept 2 Search Terms: Danc* OR ballet OR square danc* OR hip-hop danc* OR contemporary OR jazz danc* OR tap danc* OR modern danc* OR line danc*

*= truncation symbol, also referred to as a "wildcard."

out, key words alone were searched. Search results were then screened by two independent reviewers (KH and KK) to come to the included studies using Rayyan (Quatar Computing Research Institute, Doha, Quatar). Where disagreements occurred, a third reviewer (MA) was consulted.

Study Selection

Manuscripts were organized using reference manager software, Mendeley 1.17.13 (Mendeley Ltd., Oxford, United Kingdom). Papers were screened in multiple stages. Duplicate studies were first removed by the software and then by hand, followed by screening of titles and abstracts to remove irrelevant studies using the inclusion and exclusion criteria (Table 1). Full studies were then obtained, either through institutional access or by direct contact with the author, to ascertain their suitability for inclusion. Finally, reference lists were screened to identify relevant studies missed by the search.

Data Extraction

The following data were extracted from each study: study design, population (sample size, sex, age, genre of dance, and level of training), details of protocol, and result of turnout measurement in degrees. Details of the protocol recorded include: element of turnout assessed (HER, NHCTO, or TTO), side (right, left, or both), type of motion (active or passive), position (standing, sitting, prone, or supine), instrumentation for measurement, and sorting variable (e.g., injured and uninjured). In addition, intra-class correlation coefficient (ICC), standard error of measure (SEM), Pearson's correlation (R), and Chronbach alpha coefficients were extrapolated from all studies (as available) in order to present relative reliability of data and allow for interpretation. A desirable measure of relative reliability should reflect degree of correlation as well as agreement between measurements. Intra-class correlation coefficients would allow for both aspects; for this reason we added ICCs values (0.0-1.0), including the type (single rate/measurement or the mean of X raters/measurements).[17,18]

Risk of Bias Assessment

Risk of bias assessment of included studies was carried out according to study type using either Newcastle-Ottawa scale, AXIS tool, or PEDro scale.[19-21] The Newcastle-Ottawa scale was designed to assess either case-control or cohort studies and asks seven questions for which a study can score up to a total of nine points, focusing on the representativeness of a sample and follow-up.[19] Scores are separated into selection (up to 4 points), comparability (up to 2 points), and exposure (up to 3 points) of the test population. For the sake of simplicity, this study used an overall score out of nine total points. High scores, therefore, indicate better population selection but do not comment on the quality of the methods used. AXIS (Appraisal Tool for Cross Sectional Studies) consists of 20 questions addressing study design and risk of bias in cross-sectional studies.[20] It lacks an official scoring system due to the uncertain weighing of each element; however, for the purposes of this review and for ease of comparison, a "yes" was taken as a score of one point out of 20. This means that the overall score given is arbitrary, as it was not developed by the researchers, but for ease of comparison a higher score was taken to correlate with a higher quality study. The PEDro[17] scale was developed to assess the quality of randomized control trials and consists of 11 questions that address the internal and external validity of the study as well as how interpretable the results are. For this study, the total score reflects overall quality, while individual points pertain to likely internal and external validity and whether sufficient statistical information has been provided to interpret results.[21]

Results

The original search yielded 670 studies, which reduced to 404 when duplicates were removed. Inclusion and exclusion criteria were applied to titles and abstracts, which identified 59 full studies. Hand searching of reference lists yielded an additional two studies, for a total of 61 full studies. When the full text of the 61 studies was screened 20 were eliminated, leaving a total of 41 original research studies for inclusion in the systematic review.

Hip External Rotation (Table 4)

Twenty-eight studies were identified that measured HER; 19 were cross-sectional studies,[7-9,12,15,22-35] six case-control,[36-41] two cohort,[42,43] and one randomized control trial.[44] Passive and active ranges of motion were assessed using a variety of tools: standard goniometer, modified goniometer, digital inclinometer, and kinematic analysis. Participants were assessed in four different positions: prone (16 studies[7-9,15,23,25-28,31,34-38,44]), supine (seven studies[12,29,33,39-41,43]), sitting (six studies[7,9,30,39-42]) and standing (two studies,[24,32] both kinematic analysis). Some studies used more than one position.

When HER was measured with the dancer prone, the hip was extended, knee flexed to 90°, and the hip was then actively or passively externally rotated. For measurement in the supine position, the hip was extended and knee flexed, allowing the calves to hang over the edge of the table. In both the supine and prone positions, either actively or passively, the angle was measured between the axis of the tibia and the vertical plane in order to establish the degrees of HER. Jenkins et al.[12] measured HER in supine position at 90° of hip flexion.

Measurements in a sitting position occurred with hips and knees flexed and calves over the edge of the table. Hips were then externally rotated such that the thighs were positioned laterally relative to the trunk. Standing protocols included active movements recorded using kinematic analysis with either infrared markers[32] or "eagle eye" cameras[24] to gauge the relative positions of the components of the hip joint.

Non-Hip Contributions to Turnout (Table 5)

Nine studies recorded NHCTO, including seven cross-sectional studies,[7-9,24,29,34,45] one cohort,[43] and one case-control study.[10] Dancers were

Table 4 Studies that Measured Hip External Rotation (HER)

Study	Sample	Study Design	Motion	Position	Instrument	Validity or Reliability Testing
Cabral de Mello Viero et al. 2017[32]	17 Ballet; NS; F; 12-35 years	Cross-sectional	Active	Standing, feet in parallel position	Kinematic	NR
Davenport et al. 2016[22]	36 NS; University and Conservatory; MF; 20.8 ± 1.8 years	Cross-sectional	Passive, Active	Prone, knee flexed at 90°	Goniometer	NR
Drezewska et al. 2012[30]	49 Jazz and Classical; MF 15-32 years	Cross-sectional	Passive	Sitting, shins dangling off the table and thighs stabilized	Goniometer	NR
Duthon et al. 2013[33]	20 Ballet; Prof and Advanced; F; 18-39 years	Cross-sectional	Passive	Supine, hip and knee flexed at 90°	Goniometer	NR
Grossman et al. 2008[9]	14 Ballet; Collegiate; F; Age not specified	Cross-sectional	Passive	Prone, knee flexed at 90°; Sitting, hips and knees flexed at 90°	Goniometer	Intra-tester reliability: r = 0.78 (right) and 0.77 (left) Validity = comparison with standing turnout
Hafiz et al. 2016[34]	80 Ballet; Prof and Collegiate; F; 19.6 ± 4.7 years	Cross-sectional	Passive	Prone, hip in neutral flexion and extension and neutral abduction and adduction, knee passively flexed at 90°	Digital inclinometer	NR
Jenkins et al. 2013[12]	47 Contemporary; Conservatory; F; 19.9 ± 2.5 years	Cross-sectional	Passive	Supine, 90° hip Flexion	Goniometer	NR
Khoo-Summers et al. 2013[7]	23 Var; Collegiate; F; 18-21 years	Cross-sectional	Active	Prone, hip in neutral abduction and adduction and knee flexed at 90°; Sitting, hip in neutral abduction and adduction with knee in 90° of flexion.	Goniometer	NR
Kivlan et al. 2016[35]	28 Var; Collegiate; F; 18-22 years	Cross-sectional	Passive	Prone, knee flexed at 90°	Goniometer	Intra-tester reliability ICC = 0.82-0.90

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Table 4 Studies that Measured Hip External Rotation (HER)

Study	Sample	Study Design	Motion	Position	Instrument	Validity or Reliability Testing
Martinez et al. 2014[23]	60 Ballet; Competitive and Recreational; F; 12-18 years	Cross-sectional	Passive	Prone, hip positioned at a neutral angle, knee at 90° of flexion; contralateral limb at 30° of hip abduction	Goniometer	NR
Pappas et al. 2008[24]	8 Var; Prof; MF; 28.1 ± 3.2 years	Cross-sectional	Active	Standing, knees straight	Kinematic	NR
Quanbeck et al. 2017[8]	10 Ballet and Contemporary; Prof and Pre-prof; F; 18-23 years	Cross-sectional	Passive	Prone, hip fully extended, knee flexed at 90°	Goniometer	NR
Steinberg et al. 2012 (1)[25]	1359 Var; Var; F; 8-20 years	Cross-sectional	Passive	Prone, hips in a neutral position of flexion/extension and abduction/adduction.	Goniometer	Test-retest r = 0.89; Inter-tester: r = 0.741-0.951
Steinberg et al. 2011[26]	1082 non-professional; Var; F; 8-16 years	Cross-sectional	Passive	Prone, hips in a neutral position of flexion/extension and abduction/adduction.	Goniometer	ICC: intra-tester = 0.89-0.96 Inter-tester = 0.74-0.95
Steinberg et al. 2013[27]	569 Var; Var; F; 8-16 years	Cross-sectional	Passive	Prone, hips in a neutral position of flexion/extension and abduction/adduction.	Goniometer	ICC: intra-tester = 0.89-0.96 Inter-tester = 0.74-0.95
Steinberg et al. 2012 (2)[28]	1336 Var; Var; F; 8-16 years	Cross-sectional	Passive	Prone, hips in a neutral position of flexion/extension and abduction/adduction.	Goniometer	ICC: intra-tester = 0.896-0.951 Inter-tester = 0.741--0.951 Intra-tester: LOA: -0.75 (3.59) Inter-tester: LOA: -0.75 (7.30)
Steinberg et al. 2015[31]	1336 Var; Var; F; 8-16 years	Cross-sectional	Passive	Prone, hips in a neutral position of flexion/extension and abduction/adduction.	Goniometer	ICC: intra-tester = 0.896-0.964 Inter-tester = 0.74-0.95
van Merkensteijn et al. 2015[15]	22 Var; University; MF; 21.3 ± 1.3 years	Cross-sectional	Active	Prone, hips in a neutral position, knee flexed at 90°	Goniometer	NR
Washington et al. 2016[29]	45 Ballet; Prof; MF; 25.9 ± 5.4 years	Cross-sectional	Passive, Active	Supine, knee flexed at 90° over the end of a treatment table; neutral hip and pelvic position	Digital inclinometer	NR

(continued on next page)

Table 4 Studies that Measured Hip External Rotation (HER)

Study	Sample	Study Design	Motion	Position	Instrument	Validity or Reliability Testing
Mayes et al. 2016 (1)[40]	49 Ballet; Prof or retired; MF; 25-47 years	Case-control	Passive	Supine, 0° of hip flexion Sitting, 90° of hip flexion	Digital inclinometer	ICC: intra-tester = reported for MRI features (labral tears; cartilage defect; lateral center edge angles) Hip ER:NR
Mayes et al. 2016 (2)[39]	49 Ballet; Prof or retired; MF; 25-47 years	Case-control	Passive	Supine, 0° of hip flexion Sitting, 90° of hip flexion	Digital inclinometer	ICC intra-tester: Hip ER at 0° (ICC) 0.90; 95% confidence interval (CI), 0.57-0.98] ICC intra-tester: hip ER at 90° (ICC = 0.77; 95% CI, 0.16-0.94)
Mayes et al. 2017[41]	33 Ballet; Prof; MF; 18-41 years	Case-control	Passive	Supine, 0° of hip flexion and abduction	Digital inclinometer	ICC intra-tester reliability test for morphological measures (lateral centre edge angle; neck-shaft angle; anterior alpha angle; superior alpha angle; acetabular version angle) Hip ER: NR
Steinberg et al. 2006[37]	1320 Var; Var; F; 8-16 years	Case-control	Passive	Prone, hips in a neutral position of flexion/extension and abduction/adduction	Goniometer	Intra-tester reliability: r = 0.899 Inter-tester reliability: r = 0.74-0.95.
Steinberg et al. 2016[36]	240 Var; Var; F; 8-16 years	Case-control	Passive	Prone, hips in a neutral position of flexion/extension and abduction/adduction	Goniometer	Intra-tester reliability ICC= 0.87-0.96 Inter-tester reliability ICC= 0.74-0.95
Steinberg et al. 2017[38]	271 Var; Pre professional; F; 10-16 years	Case-control	Passive	Prone, hips in a neutral position of flexion/extension and abduction/adduction, knees flexed at 90°	Goniometer	ICC: intra-tester = 0.89-0.96 ICC: inter-tester = 0.74-0.95
Moller et al. 2011[42]	15 Ballet; First classes; F; 6-9 years	Longitudinal single blinded cohort control	Passive	Sitting, 90° of hip and knee flexion, the back in a neutral position with the thighs resting parallel to the table	Digital inclinometer	ICC: intra-tester = 0.55 ICC: inter-tester = 0.50 Validity: 95% of the angles measured were in the range of 0.5° compared to the angles measured using a calibrated digital level as well as for the peak angle with an acceptable standard deviation of 0.39°
Sherman et al. 2014[43]	16 Ballet; Pre-prof; F; 13-17 years	Cohort interventional	Passive	Supine, hip extended and knee flexed 90° over the table's edge	Digital inclinometer	NR
Lohr et al. 2017[44]	19 Classical and Modern; NS; MF; 29.3 ± 11 years	Randomized control trial	Passive	Prone, knee bent at 90° and neutral hip position	Goniometer	NR

NS: Not stated; Var: Various dance styles; Prof: Professional; M: Males; F: Females; NR: Not Reported; ICC: intraclass correlation coefficients.

Table 5 Studies that Measured Non-Hip Contributions to Turnout (NHCTO)

Study	Sample	Measurement	Study Design	Motion	Position	Instrument	Reliability Testing
Carter et al. 2017[45]	19 Ballet and Modern; University; F; 17.9 ± 0.9 years	Tibiofemoral anteversion	Cross-sectional	Passive	Sitting, hip in neutral relative to the frontal and transverse planes.	Goniometer	ICC: intratester = 0.93
Grossman et al. 2008[9]	14 Ballet; Collegiate; F; NS	Tibial torsion and knee contributions	Cross-sectional	Passive	Tibial torsion: supine; Knee contributions: supine	Tibial torsion: MRI; Knee contributions: Retro-Reflective Markers	Values = hip external rotation summed with tibial torsion compared with total passive turnout Prone: r = 56 (mean right and left) Seated: r = 53 (mean right and left) Validity = comparison with standing turnout
Hafiz et al. 2016[34]	80 Ballet; Prof and Tertiary; F; 19.6 ± 4.7 years	Femoral version	Cross-sectional	Passive	Supine, hips in neutral position	Ultrasound scan	NR – refers to previous study
Khoo-Summers et al. 2013[7]	23 Var; Collegiate; F; 19.5 ± 1.1 years	Tibial torsion	Retrospective cohort/cross-sectional	Passive	Sitting, hip in neutral abduction, adduction, and rotation	Goniometer	NR
Pappas et al. 2008[24]	8 Var; Prof; MF; 28.1 ± 3.2 years	Knee contributions	Cross-sectional	Active	Standing	Kinematic	NR
Quanbeck et al. 2017[8]	10 Ballet and Contemporary; Prof and Pre-prof; F; 18-23 years	Femoral version, thigh-foot angle, transmalleolar angle	Cross-sectional	Passive	Femoral version: prone, hip at full extension and the knee at 90°; Thigh-foot angle: prone, hip at full extension and knee at 90°; Transmalleolar angle: supine lying, knee extended	Femoral version: goniometer; Thigh-foot angle: goniometer; Transmalleolar angle: digital inclinometer	NR
Washington et al. 2016[29]	45 Ballet; Prof; MF; 25.9 ± 5.4 years	Below hip external rotation	Cross-sectional	Passive Active	Supine, knee flexed at 90°, neutral spine	Calculated difference between active, passive HER and TTO	NR
Sherman et al. 2014[43]	16 Ballet; Pre-prof; F; 13-17 years	Tibial torsion	Cohort interventional	Passive	Prone, knees flexed at 90° off the table	Goniometer	NR
Sutton-Traina et al. 2015[10]	23 Var; Prof and Collegiate; F; 19.5 ± 7 years	Femoral version	Case-control (cross-sectional)	NR	Supine, knees flexed 90° and lower legs off the table with the feet flat on a box	Ultrasound scan and digital inclinometer	ICC: intra-tester = 0.95 (SEM) of 1.1° for femoral version

Sample: N; Genre of dance; Level of training; Sex; Age (mean or range); NR: Not reported.

Table 6 Studies that Measured Total Turnout (TTO)

Study	Sample	Study Design	Motion	Position	Instrument	Reliability Testing
Carter et al. 2017[45]	19 Ballet and Modern; University; F; 17.9 ± 0.9 years	Cross-sectional	Functional	Standing, first position following demi-plie	Paper	Intratester reliability tested NHCTO measures (see Table 5)
Cimelli et al. 2012[51]	12 Contemporary; Prof; MF; 26.8 ± 3.9 years	Cross-sectional	Functional	Standing, first position following demi-plie	Paper	ICC: intratester = 0.65-0.99
Filipa et al. 2013[4]	10 Ballet; Rec; F; 5-9 years	Cross-sectional	Functional	Standing, first position	Paper	ICC = 0.82 (cited)
Grossman et al. 2008[9]	14 Ballet; Collegiate; F; Age NS	Cross-sectional	Passive, Active, Functional	Passive: Supine, first position Functional: Standing, first position Active: Standing, first position	Passive: goniometer, Functional: rotational disks Active: goniometer,	Intratester passive turnout; right: r = .78, $p < 0.01$; left r = .77, $p < 0.01$ Validity: TAT and Functional TO (tester #1, $p < 0.01$; tester #2 $p < 0.05$)
Hafiz et al. 2016[34]	80 Ballet; Prof and Collegiate; F; 19.6 ± 4.7 years	Cross-sectional	Active	Standing, first position	Rotational disks	NR
Harmon-Matthews et al. 2016[46]	95 Ballet and Modern; Prof, Academy and Collegiate; MF; Prof: 26.5 years; Academy: 15.2 years; Collegiate: 19.9 years old	Cross-sectional	Active, Functional	Active: standing, first positionn Functional: standing, first position®	Active: floor protractor (FP) Functional: Functional Footprints®	Post-hoc intertester reliability "good to excellent" for FP, RI
Hopper et al. 2016[47]	13 NS; Academy; MF; 19.2 ± 1.3	Cross-sectional	Functional	Standing, (5 ballet steps)	Kinematic	NR
Iunes et al. 2016[6]	52 Ballet; Var; F; 8-13 years	Cross-sectional	Functional	Standing, first position	Photo	Reliability and validity values cited in studies in Portuguese from other sources

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Table 6 Studies that Measured Total Turnout (TTO)

Study	Sample	Study Design	Motion	Position	Instrument	Reliability Testing
Jenkins et al. 2013[12]	47 Contemporary and ballet; Conservatory; F; 19.9 ± 2.51 years	Cross-sectional	Passive, Functional	Passive: supine, knee extended; Active: standing, alignment of second toe with the vertical line	Passive: goniometer, Active: Functional Footprints®	NR
Khoo-Summers et al. 2013[7]	23 Var; Collegiate; F; 19.5 ± 1.1 years	Cross-sectional	Functional	Standing, first position	Goniometer	NR
Lohr et al. 2017[44]	19 Classical and Modern; NS; MF; 29.3 ± 11 years	Randomized control trial	Active	Standing, external rotation with outstretched knee and hip joints	Functional Footprints®	NR
Quanbeck et al. 2017[8]	10 Ballet and Contemporary; Prof and Pre-prof; F; 18-23 years	Cross-sectional	Active, Functional	Standing, first position	Active: kinematic on rotational disks; Functional: pressure mat	NR
Welsh et al. 2008[53]	17 NS; University; NS; 18-32 years	Cross-sectional	Passive, Active, Functional	Passive: supine; neutral alignment at the pelvis and lower back, knees extended. Functional: standing; first position Active: standing, first position	Passive: goniometer, Functional: goniometer, Active: rotational disks	Chronbach's alpha: Functional turnout = 0.99 Passive turnout = 0.98 Active turnout = 0.98
van Merkensteijn et al. 2015[15]	22 Var; University; MF; 21.3 ± 1.3 years	Cross-sectional	Functional	Standing, first position	Paper	NR
Walker et al. 2011[50]	334 Ballet and Contemporary; Auditioned part-time school; MF; 10-18 years	Cross-sectional	Active	Standing, first position	Functional Footprints®	NR

(continued on next page)

Table 6 Studies that Measured Total Turnout (TTO)

Study	Sample	Study Design	Motion	Position	Instrument	Reliability Testing
Washington et al. 2016[29]	45 Ballet; Prof; MF; 25.9 ± 5.4 years	Cross-sectional	Functional	Standing, first position neutral pelvis	Paper	NR
Imura et al. 2017[48]	12 Ballet; Prof; F; 30 ± 1 years	Cross-sectional	Functional	Standing, first position after landing from sauté	Kinematic	NR
Aujla et al. 2015[52]	280 Contemporary; Var; F; 10-18 years	Prospective cohort	Active	Standing, hips externally rotated and knees extended	Functional Footprints®	NR
Sherman et al. 2014[43]	15 Ballet; Pre-prof; F; 13-17 years	Cohort interventional	Passive, Active, Functional	Passive: supine; foot held in dorsiflexion to lock the hindfoot and control abduction Functional: standing; first position Active: standing; first position	Passive: goniometer, Functional: goniometer, Active: rotational disks	NR
Pata et al. 2014[14]	6 Ballet and Modern; University; F; NR	Cohort interventional	Active	Standing, first position	Rotational disks	Inter-tester reliability = 100%
Sutton-Traina et al. 2015[10]	23 Var; Prof and Collegiate; F; 19.5 ± 7 years	Case-control	Passive, Active	Passive: supine; relaxed spinal alignment, legs extended and feet dorsiflexed to neutral Active: standing, first position	Passive: goniometer, Active: Functional Footprints®	ICC: Supine intra-tester = 0.98 (cited) Standing intra-tester = 0.97 SEM of 1.08° for total active disk turnout

Sample: N; Genre of dance; Level of training; Gender; Age (mean or range); NR: Not reported.

again either prone, supine, sitting, or standing, but measurement protocols were more diverse. Tibial torsion was measured with both goniometry[7,43] and MRI.[9] Knee contributions were measured using kinematic analysis, either supine with the assessor passively rotating the limb externally,[9] or standing, with the measurement indicating the proportion of active turnout contributed by the knee.[24] Femoral version was measured using ultrasound,[10,34] standard goniometer,[24] and digital inclinometer.[10] Washington et al.[29] and van Merkensteijn et al.[15] used a calculation to determine the degree of turnout originating from below the hip. This included subtracting the recorded value of active HER from recorded standing total turnout (TTO).

Total Turnout (Table 6)

Twenty-two studies assessed total turnout, comprising 17 cross-sectional studies,[4,6-9,12,14,15,29,34,43,45-51] three cohort,[14,43,52] one case-control study,[10] and one randomized control trial.[44] All studies measured either functional turnout (standing on the floor or a fixed measurement device), or active turnout (standing on a low friction device: rotational disks or Functional Footprints®). Moreover, five studies assessed passive total turnout, all of which were carried out using a goniometer with the dancer supine and the lower limb in full extension.[9,10,12,43,53] All studies were in agreement that the axis for measurement ran from the midpoint of the heel through the second metatarsal. Functional turnout was measured on paper (by drawing around dancers' feet and measuring the intersecting angle),[4,29,45,51] on pressure mats,[8] on a floor protractor,[46] using a goniometer,[7,9,43,53] from a photograph,[6] or through kinematic motion analysis.[47,48] Active turnout was measured using rotational disks,[9,14,42,43,53] Functional Footprints®,[10,12,44,46,49,50,52] or kinematic analysis on rotational disks.[8]

Reliability Testing

Reliability varied between different protocols used for measurement of hip external rotation. Mayes et al.[39] recorded ICC intra-tester reliability of HER at 0° (ICC) 0.90, 95% confidence interval (CI), 0.57-0.98, and hip ER at 90° (ICC = 0.77; 95% CI, 0.16-0.94). Grossman et al.,[9] Steinberg et al.,[25-28,31,36-38] and Kivlan et al.[35] presented reliability results for measurement in prone, recording ICC of 0.78, 0.925, and 0.82-0.90, respectively, for intra-tester reliability. Steinberg et al. also reported a prone position inter-tester reliability of 0.74-0.95[25-28,31,36-38]; the same ICC for inter- and intra-tester reliability was reported in their eight publications that used the same measurement protocol. In contrast with these, Moller et al.[42] reported ICC of 0.55 (intra-tester) and 0.50 (inter-tester) for measurement in a seated position. As to NHCTO, Carter et al.[45] reported intra-tester ICC of 0.93 on their measurement of tibiofemoral anteversion (seated position), and Sutton-Traina et al.[10] reported 0.95 for measurement of femoral version (supine position). No studies reported inter-tester reliability for NHCTO. As to total turnout measurement, intra-tester reliability ranged from 0.65-0.99. Welsh et al.[53] reported the Chronbach's alpha for functional (= 0.99), passive (= 0.98), and active turnout (= 0.98).[53] Pata et al.[14] recorded an inter-tester agreement of 100% in their measurement of standing active turnout, and Harmon-Matthews et al.[46] recorded post hoc inter-tester reliability as "good to excellent."

Risk of Bias Assessment

As mentioned previously, studies were assessed for risk of bias using either the Newcastle-Ottawa scale, PEDro score, or AXIS tool.[19-21] Cross-sectional studies were scored using the AXIS tool, and scores ranged from 11 to 15 out of 20.[20] The Newcastle-Ottawa scale was used to assess cohort and case control studies (two editions of the questionnaire).[19] Cohort studies all scored 6 out of 9, except for one study[42] that scored 8 out of 9. All case-control studies scored 8 out of 9, except for one[10] that scored 5 out of 9. Because the outcome of interest to this review was the protocol used in each study, all studies were included irrespective of their risk of bias assessment score. All studies scored above half the points attainable from their respective assessment tools.

Discussion

The aim of this systematic review was to describe the methods currently used to measure turnout in dance medicine and science research, thereby updating the literature since the Champion and Chatfield review of 2008.[13] Turnout is a basic element of classical dance technique and is frequently measured by health practitioners for research and screening purposes. This review has identified a variety of protocols used in the measurement of turnout. Since the Champion and Chatfield review, there has been an increase in the literature measuring turnout, as well as the overall quality of methods employed; however, the observed overriding feature remains a lack of a standard measurement protocol, which continues to prevent reliable comparison of results.[13] Although an increased number of studies have included reliability values as per Champion and Chatfield's recommendations, it was noticed that measurements of inter- and intra-rater reliability include mainly relative measures, such as intra-class correlation coefficient (ICC) values, with two studies implementing the use of absolute reliability measures, such as standard error of measure (SEM)[10] and limits of agreement (LOA).[38] One study included Pearson R values,[9] but these values should be interpreted cautiously in reliability testing as they cannot detect systematic error.[17]

Studies included in the present review have employed standard goniometers rather than visual estimates as per Champion and Chatfield recommendations; this was particularly apparent for HER measurements. With specific regard to measurement of HER, while prone, supine, and sitting positions only were reported by Champion and Chatfield, the standing position has subsequently been used in two studies.[32,24] Hip external rotation remains the most common turnout measurement; however, an increased number of studies have been investigating TTO (N = 22; N = 4 passive TTO) and NHCTO (N = 9). Overall, researchers have employed fairly robust methodological approaches, with the risk of bias assessment revealing all studies scored above half the points attainable from their respective assessment tools. Champion and Chatfield did not include risk of bias assessment and therefore it is not possible to make a direct comparison to that study.

Although all of the subjects included in this review were from a dance background, the population was heterogeneous. There was a large age range among studies, and since joint ROM has been shown to change with age, this will have an important impact on comparability of results, in addition to inconsistencies in level of training. Although the overriding dance discipline was ballet, it is very common for dancers to be trained in more than one discipline. The emphasis on turnout in other dance genres is more variable, so training discrepancies may affect external validity and comparability of results.

The ability of a dancer to achieve satisfactory turnout is influenced by many factors. Femoral version was a feature measured by three studies that defined where the axis of the lower limb naturally lies in relation to the hip.[8,10,34] If a dancer has a lesser degree of femoral version the lower limb will be positioned in an already externally rotated position, suggesting that less strength and coordination is required to reach a greater turnout angle. Tibial torsion is the natural (usually external) rotation of the tibia from the proximal to the distal end of the bone[9] (Fig. 3). This was measured in three studies using goniometry and MRI.[7,9,43] In addition, Steinberg et al.[36] found a significant increase in the amount of turnout dancers can achieve if they have joint hypermobility, inferring that some if not all of turnout ability is predetermined anatomically.

Twenty-one of the 41 studies included in this review used reliability tested protocols. The overall lack of absolute reliability and validity testing was a common methodological limitation. Relative reliability refers to the ability of a measure to differentiate between testers, and it is measured by the use of ICC. Nevertheless, ICC can provide only limited information about measurement error. Therefore, the absolute reliability, such as the SEM, should also be used to determine the extent of measurement error.[17] One study reported SEM values in addition to ICC values.[10]

Measurements used to assess TTO and its components are often subjective and, thus, are vulnerable to deficits in reliability. For example, in the measurement of passive HER, the assessor will externally rotate the limb and judge whether to stop at the absolute limit of movement or when resistance is first felt from the joint. Moller et al.[42] tested intra- and interrater reliability of HER in a seated position and found moderate reliability, whereas other measures in the same study (including lumbar lordosis) had high reliability. This could be due to the dynamic nature of HER measurement, but it casts doubt on the reliability of other HER measures.[42] Champion and Chatfield produced guidelines for measurement of HER, including prone as the recommended position.[13] This position allows HER to be measured by one practitioner, but range of motion may be prematurely limited by the calf of the test leg contacting the contralateral leg. This may impact measurement validity and is a particular problem in more flexible populations such as dancers.[33] In addition, the supine position might be considered more valid as it allows for the measurement of active ROM against gravity.

Hip external rotation was the most commonly measured component of turnout, used in 28 studies. Hamilton et al.[54] found 40% of TTO originates from below the knee, which was supported by the findings of Quanbeck et al.,[8] who reported a contribution of only 36% from HER. Measurement of HER alone disregards the contribution to TTO of structures below the hip and, therefore, could be considered to lack validity as a measure of turnout. Also, in seven studies, HER was measured from a seated position.[7,9,30,39-42] Due to the altered position of the pelvis and consequential impacts on HER, a seated measure is unlikely to yield the same result as one with the hip in an extended position and is, therefore, less externally valid.

Grossman et al.[9] compared the validity and reliability of measuring turnout using goniometry with MRI and retro-reflective markers. With the dancer supine and the knee in full extension, they used retro-reflective markers with the researcher externally rotating the lower limb to assess contributions of the knee to passive TTO. Grossman et al. reported that, due to the "screw home" mechanism of the knee, with the knee in full extension, the tibia and femur acted as one unit. However, Quanbeck et al.[8] used a kinematic protocol with rotational disks and found that a summed total of 41° external rotation originated in the knee. This highlights validity issues of non-weightbearing methods to elicit a movement that, in practice, is weightbearing, meaning lower limb structures form a closed kinetic chain.[55]

Grossman et al.[9] also measured tibial torsion using MRI and found an average result of 35° of torsion. Conversely, Sherman et al.[43] measured tibial torsion using a standard goniometer and found 5° and 10° for right and left legs, respectively. Although Grossman et al. noted variations between participants, this is a substantial difference considering their seemingly similar populations, suggesting the need to test for reliability the measurement of tibial torsion using goniometry.

Two studies calculated NHCTO as the difference between total standing turnout and active supine HER. However, this relies on the reliability of two measurement protocols, one of which employs an open kinetic chain (HER) and the other a closed kinetic chain (TTO).[15,29]

The highest average active turnout was recorded as 159° by Iunes et al.[6]

Despite this being the highest value, it still did not reach the 180º required for "ideal turnout."[4-7] This suggests that 180° might not be an achievable ideal for which to strive. It has been suggested that dancers might achieve a greater degree of turnout during dynamic moves, such as landing from a spinning leap, in which different forces are applied.[9] If this is the case, kinematic protocols may be more appropriate measures of turnout ability. In addition, those active protocols that use rotational disks or Functional Footprints® to reduce friction with the ground may be of reduced validity, although they do serve to assess the strength and control a dancer employs in the movement. Interestingly, Functional Footprints® was designed for the improvement of dance technique, not the measurement of turnout, but given its use in seven studies,[10,12,44,46,49,50,52] it seems to have become a popular tool.[56]

Ballet dancers are generally expected to achieve the ideal turnout of 180°. However, given the frequent use of below-hip contributions to achieve this ideal, there are concerns that pushing turnout beyond a dancer's anatomical limits may predispose her to injury by overstretching the joints in order to achieve the desired ROM.[37] In routine screening of dancers, practices may vary from those used in research. Tools with higher validity that provide more information (e.g., kinematic analysis) may not be widely available because they are more expensive and require more expertise to use. Cheaper, more widely available tools, such as goniometers, are easy to use with minimal training and produce easily understood data, but they are more likely to be subject to deficits in reliability.[9,42,43]

Future Directions

Future study is recommended to audit how turnout parameters are measured in practice in dance institutions. Protocols used in multiple institutions should be audited to ascertain how successfully recommendations from the research have been disseminated and applied.

As this area of literature develops, it is important for researchers to concentrate on the quality of reporting to ensure reproducibility. Before any measurement instruments or assessment tools can be used for research or clinical application, their reliability must be established. Validity and reliability testing of protocols, measuring different elements of turnout in specific populations, would be a truly valuable contribution to the field. It would allow for insight into the turnout strategies employed by different dancers in order to calculate the potential impact on injury risk. Studies implementing inter- and intra-rater reliability of NHCTO measures are required with a view to producing standardized protocols and guidelines for the use of these measurements, such as the following:

1. All measurement protocols used should be rigorously tested for reliability. When citing a study that claimed high reliability, it would also be recommended that intra- and inter-tester reliability be determined.
2. In measurement of HER, the prone position has the most reliability data and allows for fixation of the contralateral hip and measurement of external rotation by one practitioner. Researchers and clinicians should be aware that range of movement may be prematurely limited by the calf of the test leg contacting the contralateral leg. Although supine position reliability data are comparable to those reported for prone position, this has not been investigated in many studies. The supine position allows for testing of range of movement against gravity; however, if the hips and pelvis are not stabilized anteriorly against the examination table, it is harder to coordinate with one practitioner. Therefore, the use of a seatbelt is encouraged to maintain pelvis position in supine if the test is carried out by one practitioner. The seated position showed lower reliability than other measures of HER and lacks external validity due to the altered position of the hip. Therefore we do not recommend it as a measure of turnout.
3. Protocols measuring NHCTO require more investigation into their reliability before a guideline can be produced. Two studies that tested intra-tester reliability for tibiofemoral anteversion (sitting position) and femoral version (supine position) showed promising results with ICC values greater than 0.90.[10,45]
4. Total turnout should be considered a valid turnout measurement, as it reflects the real position achieved in dance practice. However, researchers must consider whether sufficient information can be collected about how the dancer reached the measured degree of turnout, particularly if the research interest concerns biomechanical strategies.
5. Regarding instruments, although an increase in the use of kinematic analysis for measuring turnout was noted, cost and expertise must be considered in planning its use. Rotational disks or Functional Footprints® are useful for assessing strength and control of the movement. Goniometers remain an economic and valid option. Both can be considered for use in studies with planned application to practice in institutions.

Limitations

Despite a rigorous search strategy, it is possible that relevant studies may have been missed, although manual searches of reference lists decreased the likelihood of this and yielded two studies. Measurement of turnout, HER, or range of motion was the primary aim of 29 of the 41 studies, with the other 12 studies including measurement as part of anthropometric screening of participants. It is possible that protocols used for "routine" screening may not be as refined as those that are the main concern of a study, which may have somewhat skewed the findings of this review.

Literature reviews are fundamentally limited by the quality of the included studies; the methods of only 20 studies included here were tested for reliability or validity, which affects the ability to produce final identification of a standardized procedure. In addition, because the aim of this review was to observe the methods used to measure turnout, all studies were included regardless of risk of bias assessment scores. The AXIS tool lacks an official scoring system due to the uncertain weighting of each element, but for the purposes of this review and for ease of comparison, a "yes" was taken as a score of 1 point out of 20.

The demographics of the study populations were heterogeneous, ranging from five-year-old girls to adult professional dancers, which makes comparison of results unfeasible. The participants were also primarily female, with a mixed cohort in only 11 studies. The heterogeneity of methodologies in this study allowed for inclusion of a large volume of studies; to be able to produce more specific guidelines, a series of future reviews should be performed, each focussing on measurement of a single element of turnout. Finally, a possible limitation of this review is the search date, which refers only to results prior to January 2018.

Conclusion

This systematic review aimed to appraise methods used to measure turnout in dance medicine and science research, thereby updating the literature since the Champion and Chatfield review of 2008. Since 2008, there has been a substantial increase in the literature dealing with the measurement of turnout; however, the overriding feature remains the continued lack of a standardized measurement protocol. Two main factors have been reported as influences on the turnout ability of dancers: anatomy (degree of femoral version, tibial torsion, and joint hypermobility) and level of training. Both of these must be considered when designing measurement protocols and interpreting or comparing results. Our results, which refer only to the stated period of 2008 to 2018, suggest that HER remains the most common protocol for measuring turnout (28 of 41 studies analyzed), despite the fact that it disregards input from structures below the hip. Nevertheless, an increase in studies investigating NHCTO and TTO was noted. When analyzing results for reliability, an increased use of relative reliability measures since 2008 was noted. From the studies that were assessed for reliability, results suggest there is still a balance to be struck between the cost and ease of protocols and their reliability and validity. Absolute reliability and validity testing of all protocols needs to be implemented in all future studies before standardization can be fully achieved.

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