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Review

Assessing Table Tennis Technical Proficiency in Individuals with Disabilities: A Scoping Review

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Abstract: Table tennis is a sport that is enjoyed by many, including those with physical and intellectual disabilities. This scoping review summarised the current test protocols for assessing table tennis technical proficiency in individuals with disabilities. Relevant articles were searched through four databases (Scopus, PubMed, SPORTDiscus, and Web of Science) covering three key aspects: disability, table tennis, and technical proficiency. The search resulted in 14 studies included for data extraction, covering physical impairments, intellectual disability, and development coordination disorder. Almost all studies (93%) were conducted on well-trained para-table tennis athletes competing in high-level competitions. There exist protocols to assess service accuracy and stroke accuracy, hand–eye coordination, quality of specific skills and ball control, functional reach, and trunk rotation. The forehand topspin and backhand topspin drives were tested the most. Table tennis robots and video cameras are the common equipment used. Moving forward, future research should develop technical proficiency tests for players across all competency levels. The skill assessment criteria and scoring methods should be standardised and clearly explained. The validity and reliability of tests should be established. Lastly, there is great potential in using artificial intelligence to enhance the assessment of table tennis proficiency in individuals with disabilities.

Keywords: para-table tennis; impairment; disabled; physical; intellectual; wheelchair; skill; movement; performance; test protocol

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1. Introduction

Sport participation is vital for maintaining good health and promoting psychological well-being for individuals with disabilities [1,2]. Table tennis is a popular sport enjoyed by many, including those with physical and intellectual disabilities. Table tennis is a game played inside by two (singles) or four (doubles) players hitting a light ball over a net positioned in the middle of a 2.74 m $\times$ 1.53 m rectangular table using small bats or paddles. A game is won by the first player or pair to reach 11 points with a two-point margin. Para-table tennis is currently the third largest Paralympic sport in terms of athlete numbers and is practiced in more than 100 countries worldwide. In para-table tennis tournaments, players can compete in wheelchairs (Classes 1–5), while standing (Classes 6–10), or against other players with intellectual disabilities (Class 11). Para-table tennis largely follows the same rules as table tennis, with minor modifications regarding the service rules for players competing in wheelchairs. Para-players who cannot grip a bat firmly can use straps and elastic bandages to secure the bat to their hand. Some standing players with physical disabilities can use canes or crutches while playing the game.

In the sport of table tennis, scientific research has been conducted on the equipment and the players. For example, previous work has examined polymer coatings of the racket [3], the kinematics of the racket [4], and how ball size, ball weight, and net height [5] could impact the success of the strokes. Pertaining to the human body, there are studies on players' anthropometric profiles [6] and footwork [7–9] and the biomechanics of various table tennis strokes [10,11]. The rapid advancement in technology also facilitates heatmap analysis of players' positional behaviour [12] and pose estimation based on computer vision [13]. To comprehensively assess the motor skills of able-bodied table tennis players, the Netherlands Table Tennis Association developed the "Dutch motor skills assessment" [14]. This protocol comprises eight tests assessing gross motor function (i.e., sprint, agility, vertical jump) and ball control (i.e., speed while dribbling, aiming at target, ball skills, throwing a ball, and hand–eye coordination). With acceptable reproducibility, good internal consistency, and good prospects for validity [14], this Dutch protocol has yielded promising results in predicting future competition participation in a 9-year follow-up study [15].

In para-table tennis, however, the test protocols for motor skill and technical proficiency level are less well established. Among para-players with intellectual disabilities, Van Bissen and colleagues [16–20] have constructed a series of simulated tests and observation protocols to assess table tennis proficiency, while Wu et al. [21] attempted to classify elite players based on their performance in service, return service, and other table tennis skills. For players with physical impairments, some studies have examined the biomechanical movement patterns [22,23], functional reach abilities [24,25], and trunk rotational function [26]. Most recently, Galas et al. [27] developed a battery of six tests for the evaluation of stroke accuracy and service precision in 23 elite players with physical or intellectual disabilities. As there exists a wide range of tests applied to players with different types of disabilities, it will be useful to synthesise information on the various assessment protocols via a scoping review. A previous scoping review on the biomechanics of table tennis manoeuvres in able-bodied players has systematically summarised useful findings to improve training regimes for better table tennis performance [28]. As the movement characteristics differed between able-bodied and para-table tennis players [22,23], a scoping review specifically on individuals with disabilities is warranted.

The aim of this scoping review was to summarise the current protocols used to assess the technical proficiency of table tennis skills among individuals with disabilities. Findings from this review will inform sports coaches, para-athletes, and physiotherapists on practical assessment protocols and facilitate the future development of table tennis for individuals with various types of disabilities.

2. Materials and Methods

2.1. Research Question

Guided by the Patient, Intervention, Comparator, Outcome, and Study (PICOS) framework [29], the research question of this study is "What are protocols used to assess table tennis technical proficiency in individuals with disabilities?" Details of the PICOS criteria are explained in Table 1.

Table 1. Search strategies guided by the Patient, Intervention, Comparator, Outcome, and Study (PICOS) framework.

Criteria		Description
P	Population	Individuals with physical or intellectual disabilities; no restriction on age or sex.
I	Intervention	Table tennis.
C	Comparison	Not applicable.
O	Outcome	Technical proficiency of table tennis tasks.
S	Study Design	Any original studies.

2.2. Search Strategy

A comprehensive search was performed for relevant articles through four databases (Scopus, PubMed, SPORTDiscus, and Web of Science). The search terms covered three key aspects: disability, table tennis, and technical proficiency. The search terms used in all databases included (disab* OR para* OR impair* OR special OR wheelchair) AND ("table tennis" OR "table-tennis" OR "ping pong" OR "ping-pong") AND ("technical proficiency" OR techni* OR skill* OR movement OR performance). In addition, hand searching of the reference lists of identified articles was conducted to gather additional relevant articles for the review. Figure 1 provides an overview of the screening and selection process.

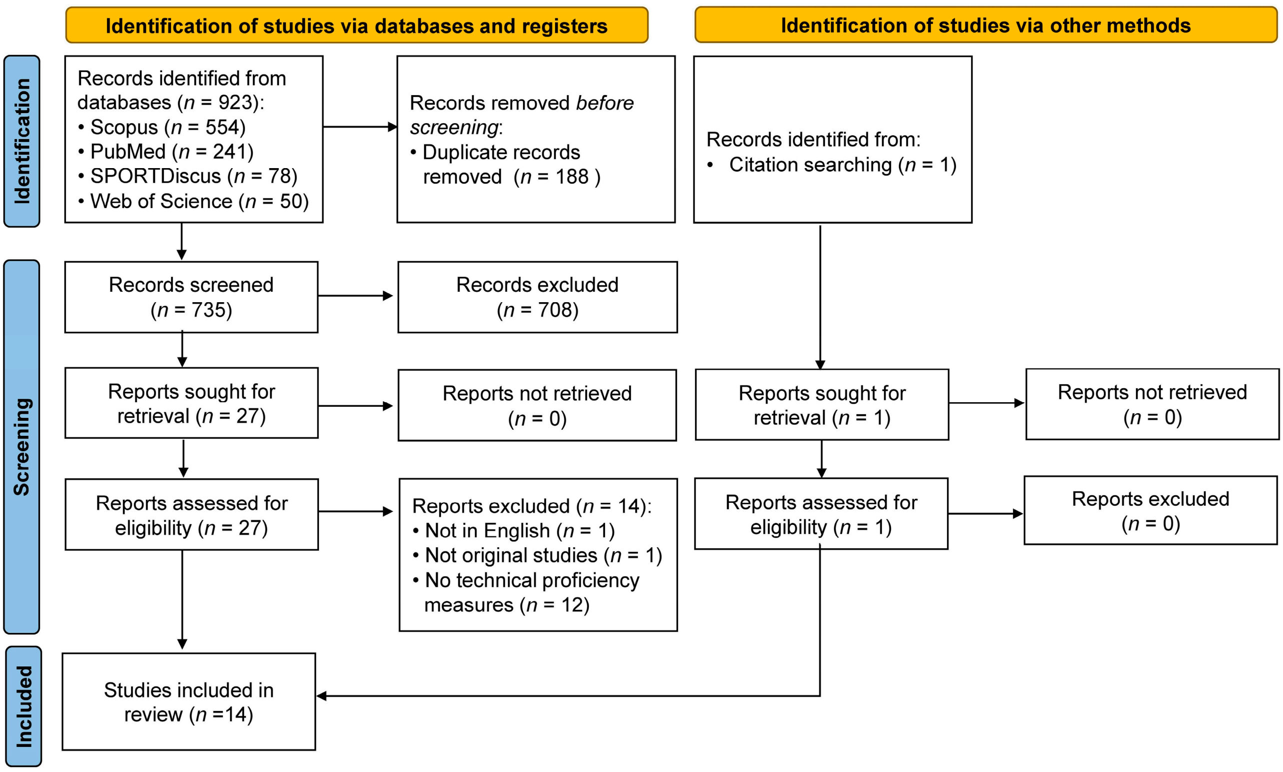

Figure 1. PRISMA flow chart illustrating the identification, screening, and inclusion phases of the scoping review.

2.3. Eligibility Criteria

Studies were considered eligible for inclusion if they incorporated protocols to assess the technical proficiency of specific table tennis tasks in individuals with disabilities. Eligibility criteria for study inclusion were as follows: (i) dates ranging from 1 January 2000 to 14 February 2024; (ii) articles written in English; (iii) original peer-reviewed articles; (iv) articles including individuals with physical or intellectual disabilities; and (v) articles reporting measures of technical proficiency in table tennis tasks. Articles were excluded if they focused on virtual table tennis, exergaming, eSports games, match analysis, characteristics of the balls, or other outcomes not directly related to the technical proficiency specific to table tennis (e.g., physical fitness, psychological measures, environmental factors). Conference abstracts, dissertations, theses, and other non-peer-reviewed articles were excluded. Studies examining sports injuries among able-bodied table tennis players without pre-existing long-term disabilities were also excluded.

2.4. Selection of Studies

Title and abstract screening and the removal of duplicates were completed in Covidence (www.covidence.org) access on 14 February 2024. One author (PWK) examined the titles and abstracts of all possibly pertinent papers for eligibility. The full texts of articles that met the criteria for inclusion were then retrieved and screened. The screening was subsequently verified by a second author (CM). There were no disagreements between the two reviewers and hence a third independent reviewer was not needed.

2.5. Data Extraction

The data extraction of eligible articles was first performed manually by one author and later confirmed by another author. Any discrepancies were resolved via discussion. Extracted information concerned the following: details of publication, participant characteristics (including sample size, demographics, table tennis experience, and types of disability), table tennis-specific technical proficiency tests, and key findings. Results of cognitive tests or general motor abilities (e.g., simple reaction time) that were not table tennis-specific were not extracted. Studies are arranged by alphabetical order of the first author's last name followed by the year of publication.

3. Results

3.1. Overview of Study Characteristics

A total of 923 articles were identified through the four databases, with 188 duplicates removed and 708 deemed irrelevant after review of the title and abstract. Of the 27 full-text articles assessed for eligibility, 14 were excluded (non-English article, n = 1; non-original article, n = 1; no technical proficiency measures, n = 12). One additional article [21] was identified from the reference list of included articles, totalling 28 publications to be included in the final analysis. The study characteristics, table tennis technical proficiency test protocols, and key findings are summarised in Tables 2–4.

The 14 studies included in this review covered various types of disabilities, including intellectual disability, physical disabilities, and developmental coordination disorders (DCD) (Figure 2a). There were more studies on wheelchair players (n = 5) compared with standing players (n = 2) with physical impairments. Excluding the two studies that did not report the sex of the participants [24,30], there were more male (n = 351, 68.3%) than female (n = 163, 31.7%) participants. The table tennis-specific test protocols were categorised as accuracy (n = 5, Table 2), skill and control (n = 9, Table 3), and functional reach and trunk rotation (n = 3, Table 4). Almost all studies (n = 13) involved competitive para-table tennis players. The sample size was generally small (n = 1 to 88 participants with disabilities), with a mixture of both males and females.

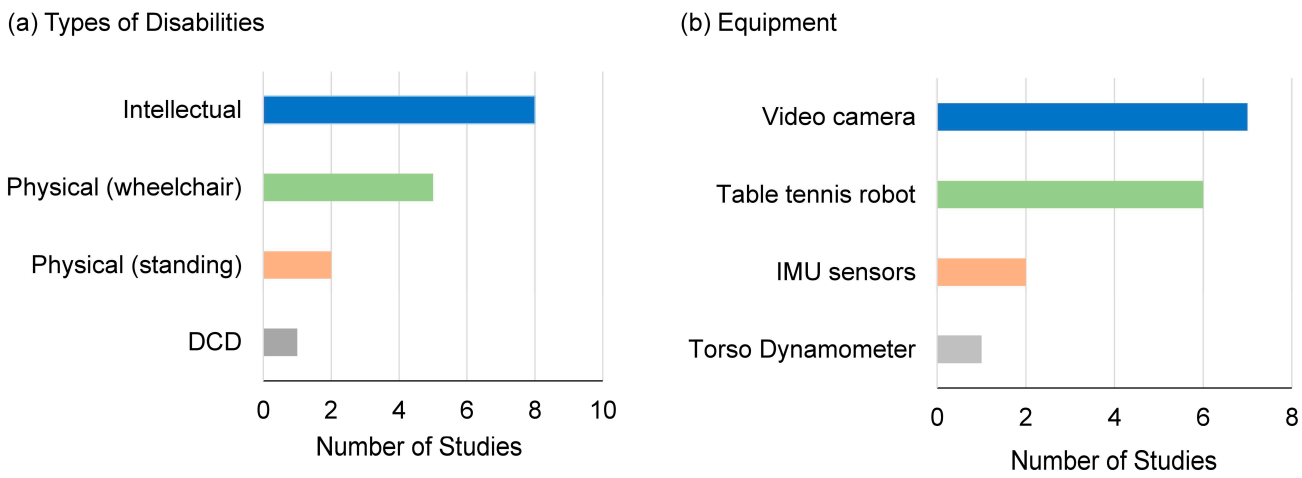

Figure 2. Number of studies organised by (**a**) types of disabilities and (**b**) equipment used in the table tennis-specific tests. DCD denotes developmental coordination disorder; IMU denotes inertial measurement unit.

Table 2. Summary of studies (n = 5) assessing the accuracy of table tennis technical proficiency in individuals with disabilities.

Articles	Country/Region	Participants	Protocols	Key Findings
Galas et al. [27]	Poland	23 para-table tennis players (16 males, 7 females) in the senior Polish para-table tennis team (M_{Age} 31.8 ± 12.22 years; M_{Play} 16.9 ± 10.5 years; M_{Week} 9.7 ± 4.7 h): • Wheelchair (n = 8); • Standing (n = 10); • ID (n = 5).	Stroke accuracy was assessed at high ball speed (80 balls per minute) delivered by a robot: • Forehand; • Backhand; • Displacement (alternate between forward and backhand). During the forehand and backhand skill speed tests, the balls were thrown to various points on the table, and the player had to make 20 topspin forehand or backhand hits within 15 s.During the displacement speed test, the player alternated between forehand and backhand topspin hits. They needed to hit the table diagonally across the table.Service Accuracy: • Short service; • Extreme side service; • Target service. The player was instructed to serve the ball to an area demarcated by lines drawn across the width of the table. Scores of 5, 3, or 1 point depending on where the ball hit the table.	Reliability over 3 sessions: slight agreement for extreme side service (ICC = 0.25) and strong agreement for the other 5 tests (ICC = 0.52–0.66).No difference between types of disability; test results not correlated with world rankings.
Smits-Engelsman et al. [31]	South Africa	50 (25 boys, 25 girls) Grade 1 to Grade 3 children (M_{Age} 7.2 ± 1.0 years), including 16 developmental coordination disorders (DCDs) and 34 typically developing (TD).	"Cup Ping-Pong" game: This game was performed in small groups of 2–4 children supervised by two physiotherapists. Participants were instructed to throw a Ping-Pong (table tennis) ball against the wall at 1 m distance and catch it in a plastic beer cup in the other hand. A total of 10 trials were conducted and the number of times the ball was caught was counted.	Both children with DCD and TD performed better on trained and non-trained balls, and balance and agility tasks after 10 weeks of training via active video games.
Van Biesen et al. [16]	16 countries from 3 different continents (Europe, Africa, and Asia)	47 male elite table tennis players: Players with ID participated in INAS-FID competition (n = 39, M_{Age} 28.3 ± 7.3 years, M_{IQ} 61.7 ± 7.9); Players without ID competing at national level (n = 8, M_{Age} 22.7 ± 10.3 years).	Table tennis-specific test battery for service return accuracy: • Received serves from a robot with varied ball speeds, directions, spins, and landing areas; • Serves to be returned to a fixed target. Athletes received 16 sets of 15 identical serves with respect to ball speed, direction, and spin. Each serve landed on specific areas on the table at a standardised speed sufficient to prevent a second bounce on the service reception side of the net. Players were instructed to return each service to a specified target (A4 paper size) on the service return side of the table. Ball frequency was set to 1 ball every 2 s, for a total of 30 s per set. Time between the sets was 15 s and time between each block of 4 sets was 45 s.Error from the target was quantified from video analysis using Dartfish software. A 7-by-7 digital frame was constructed around the target, with each square exhibiting the same size as the target. The relative error of each return was calculated as the deviation from the target in both width (left–right) and depth (forward–backward).	The elite table tennis players with ID did not reach the same level of technical proficiency in returning serves compared to players without ID.

Table 2. *Cont.*

Articles	Country/Region	Participants	Protocols	Key Findings
Van Biesen et al. [19]	15 countries from 5 different continents (Europe, Africa, Australia, Asia, and South America)	Elite table tennis players with (n = 71) and without ID (n = 17).Players with ID (90% competed in the INAS World Championships, M_{Play} 13 ± 5 years): 41 males (M_{Age} 27.0 ± 8 years; M_{IQ} 61 ± 9); 30 females (M_{Age} 28 ± 8 years; M_{IQ} 57 ± 10). Players without ID (regional level, M_{Play} 11 ± 6 years): 12 males (M_{Age} 24 ± 12 years); 5 females (M_{Age} 20 ± 10 years).	The players were asked to play 12 series of 5 rallies against an able-bodied opponent. There were 6 service variations delivered in a standardised sequence: • No spin to backhand; • Backspin to forehand; • Topspin to middle; • Left sidespin to backhand; • Backspin–sidespin combination to forehand; • Topspin–sidespin combination to middle. Each of these variations could be either short or long, so there were 12 service types. Each player received each of the 12 service types five times in a row (five services with no spin followed by five services with backspin, etc.), resulting in a total of 60 services per player. The test battery started with the short service block for half of the players and with the long service block for the other half to control for possible fatigue or learning effects. The return accuracy was scored as • 0—miss-hit; • 1—on the table in tactically less appropriate zone; • 2—on the table in tactically appropriate zone.	Inter-rater reliability (r = 0.75); intra-rater reliability (r = 0.90) among coaches.Lower proficiency scores in players with ID than those without ID.No significant correlation (r = 0.08, p > 0.05) between the total tactical proficiency and IQ scores in players with ID.

Table 2. *Cont.*

Articles	Country/Region	Participants	Protocols	Key Findings
Wu et al. [21]	5 continents including 23 countries	87 (56 males, 31 females) international players with ID (M_{Age} 2.69 ± 8.1 years, M_{Play} 11.8 ± 7.3 years, M_{Week} 10.4 ± 6.9 h).	Service Accuracy—players were instructed to perform 6 types of service: • Long backspin to backhand; • Long backspin to forehand; • Short backspin to backhand; • Long no spin to body; • Fast ball to forehand; • Long sidespin to backhand. The service accuracy was scored as • 0—wrong service and wrong location of the ball or missed the service; • 1—poor control in service or poor location of the ball; • 2—good control in service and good location of the ball. Return Service Accuracy—players were instructed to return service using the specific skill: • Long backspin to backhand; • Long backspin to forehand; • Short no spin to forehand; • Long topspin to forehand; • Fast ball to backhand; • Long sidespin to backhand. The return service accuracy was scored as • 0—wrong control in stroke and missed the ball; • 1—poor control in stroke or poor location of the ball; • 2—good control in stroke and good location of the ball.	Recommendation of cut-off scores to classify players: ≥60 for service and return service; ≥8 items "good"; ≥3 items "reasonable" for basic skills and control.

Data are expressed as mean (standard deviation) unless otherwise stated. DCD denotes developmental coordination disorder; ID denotes intellectual disability; ICC denotes intra-class correlation; IQ denotes intelligent quotient; M denotes mean; M_{Age} denotes mean age; M_{IQ} denotes mean intelligent quotient; M_{play} denotes mean years of playing experience; M_{week} denotes mean number of training hours per week; TD denotes typically developing.

Table 3. Summary of studies (n = 9) assessing skill and control in table tennis technical proficiency in individuals with disabilities.

Articles	Country/Region	Participants	Protocols	Key Findings
Inbal et al. [30]	Israel	20 Special Olympics table tennis players (sex: NR): • Experimental group (n = 10, M_{Age} 30 ± 5 years); • Control group (n = 10, M_{Age} 32 ± 5 years).	Construction of 4 types of tests with motor actions linked to table tennis skills: • Balance (e.g., transfer of weight, standing on one leg, in-game cross steps); • Hand–eye coordination (e.g., throw and catch a ball); • Power regulation (e.g., throw a ball to target from different distances, hit the ball in-game across the net); • Motor coordination (e.g., dribbling while walking, hit the ball in-game while moving the legs). The test items were analysed and validated by 11 experts in special education, physical education, and table tennis.	Good internal consistency between items in each type of tests: Balance (n = 8 items, reliability = 0.90); Hand–eye coordination (n = 7 items, reliability = 0.83); Power regulation (n = 10 items, reliability = 0.80); Motor coordination (n = 5 items, reliability = 0.82). After 6 months of training (twice a week, 90 min per session), the experimental group performed better in all four types of motor skill compared with the control group.
Kong and Yam [22]	Singapore	International para-athlete (1 male, 51 years, Class 7, 20 years of playing experience).Able-bodied controls (9 male university students, M_{Age} 23.5 ± 1.6 years, M_{Play} 13.4 ± 2.6 years).All trained at least 2 sessions per week in the past 3 months.	Balls were delivered by a table tennis robot. Participants performed 30 trials (3 sets of 10 consecutive drives) for forehand topspin drives and 30 trials (3 sets of 10 consecutive drives) for backhand topspin drives. They were instructed to return the ball diagonally to land on the lower half of the table within the marked 0.80 m × 0.76 m zone. Returns were deemed valid when the ball landed diagonally within the target zone. Shoulder abduction/adduction angles and joint range of motion were measured using inertial sensors.	Joint range of motion of the para-player was comparable to the control group in the forehand [para-player 38°, controls32 (15)°] and larger in the backhand [para-player 35°, controls 24 (16)°].Waveform analysis revealed differences ($p < 0.05$) in movement patterns.
Lim et al. [24]	Singapore	6 wheelchair para-table tennis players (sex: NR) from the National Table Tennis Team: • Class 1 (n = 3); • Class 2 (n = 3). At least 2 years of international competitive in para-table tennis.	Sweep time (ST)—players were required to perform forehand and backhand stroke shots on balls placed in 6 different positions. The table tennis balls were propped up to 40 mm high and positioned on designated positions (maximum/intermediate/near reach for forehand and backhand). The players were required to hit the ball over the net and land it on the opposite table like a table tennis game. This task aims to replicate the full table area covered around the table by players in a rally during competition. The time taken to complete the task is the sweep time (ST).	Reference data of ST in para-athletes: • M_{ST} (Class 1: 4.92 ± 0.98 s; Class 2: 3.69 ± 0.58 s).

Table 3. *Cont.*

Articles	Country/Region	Participants	Protocols	Key Findings
Van Biesen et al. [17]	15 countries from 5 different continents (Europe, Africa, Australia, Asia, and South America)	Elite table tennis players with (n = 71) and without ID (n = 17).Players with ID competed in the INAS-FID World Table Tennis Championships: • 41 males (M_{Age} 27.0 ± 8 years; M_{IQ} 61 ± 9); • 30 females (M_{Age} 28 ± 8 years; M_{IQ} 57 ± 10). Players without ID: • 12 males (M_{Age} 24 ± 12 years); • 5 females (M_{Age} 20 ± 10 years).	To assess the technical proficiency, the player was asked to perform 10 different sets of 10 identical strokes. Players were instructed to return services delivered by a robot to the opposite side of the table using prescribed forehand and backhand strokes: • Contra; • Topspin; • Push; • Block; • Flick; • Smash. The task for the player was to perform the strokes focusing on technical correctness only. To make sure that the player knew exactly what was expected and to visualise a perfect execution of each stroke, the player was invited to a computer screen to observe a video clip with a perfect execution of the requested stroke. Each player's personal coach was present during the test to clarify to the player what was expected if needed. The test leader emphasised that good technical performance was more important than successfully hitting the ball on the table. Five experts to rate each stroke using a technical observation protocol (1—the criterion was clearly observable; 0—the criterion was not observable or was incompletely executed).	Reliability (inter-rater: ranging from 0.76 to 1.0; intra-rater: ranging from 0.96 to 1.0).Significant differences in technical proficiency of all types of strokes (except block) among players with and without ID (the latter performed better), but no gender differences regardless of disabilities.
Van Biesen et al. [18]	NR	24 elite players with mild ID: 13 males; 11 females (M_{Age} 25 ± 6 years, M_{IQ} 61 ± 9).Top 16 male and female players participated in the 2009 INAS World Championships.	The technical proficiency of the table tennis players was measured in two conditions: Simulation Testing vs. Game Play. In Simulation Testing, all players underwent a standardised test battery measuring the proficiency of 10 skills. In Game Play, players were videotaped during competition, wherein a minimum of three actual play sets per player were analysed. A set is a game wherein one of the players scores 11 points against the other player with a minimal difference of two points. Videos taken during Simulation Testing and Game Play were analysed by five table tennis experts. These experts rated the forehand and backhand stroke skills using a technical observation protocol (1—the criterion was clearly observable; 0—the criterion was not observable or was incompletely executed): • Contra; • Topspin; • Ppush; • Block; • Flick; • Smash.	Technical proficiency during standardised Simulation Testing is positively related to proficiency during Game Play in some measures (flick, topspin–forehand, and topspin–backhand) but not all.

Table 3. *Cont.*

Articles	Country/Region	Participants	Protocols	Key Findings
Van Biesen et al. [19]	15 countries from 5 different continents (Europe, Africa, Australia, Asia, and South America)	Elite table tennis players with (n = 71) and without ID (n = 17).Players with ID (90% competed in the INAS World Table Tennis Championships, M_{Play} 13 ± 5 years): 41 males (M_{Age} 27.0 ± 8 years; M_{IQ} 61 ± 9); 30 females (M_{Age} 28 ± 8 years; M_{IQ} 57 ± 10). Players without ID (regional level, M_{Play} 11 ± 6 years): 12 males (M_{Age} 24±12 years); 5 females (M_{Age} 20 ± 10 years).	Participants received 12 series of five rallies against an able-bodied opponent with instructions to "try to win each rally". There were six service variations delivered in a standardised sequence: no spin to backhand, backspin to forehand, topspin to middle, left sidespin to backhand, backspin–sidespin combination to forehand, and topspin–sidespin combination to middle. Each time a player attempted a return and subsequent rally, an expert rated the tactical proficiency (TAP) scores (0 to 2 per item): • Return accuracy; • Quality of decision; • Return effectiveness; • Variation during the rally.	Inter-rater reliability (r = 0.75); intra-rater reliability (r = 0.90) among coaches.Lower proficiency scores in players with ID than those without ID.No significant correlation (r = 0.08, p > 0.05) between the total TAP and IQ scores in players with ID.
Van Biesen et al. [20]	NR	88 well-trained players with ID (M_{Age} 27.5 ± 8.4 years; M_{IQ} 59.9 ± 9.6): • 59 males (M_{play} 12.3 ± 6.7 years; M_{week} 9.9 ± 6.0 h); • 29 females (M_{play} 11.9 ± 6.3 years; M_{week} 9.7 ± 6.3 h). Competitive players participated in several INAS competitive events in the Czech Republic, Poland, and Italy.	Test 1 Received different types of services and played rallies with an experienced player with instructions to "try to win each rally". Tactical proficiency scores (0 to 2 per item) assessed by coaches: • Return accuracy; • Quality of decision; • Return effectiveness; • Variation during the rally. Test 2 On-court observations by experts: • Service proficiency, ranging from 0 (bad execution) to 2 (perfect execution); • Return proficiency, ranging from 0 (bad execution) to 2 (perfect execution); • Rally proficiency, ranging from 0 (required combination was not mastered) to 5 (perfect execution of the skill).	Selective cognitive factors are related to tactical proficiency in table tennis among athletes with ID. Simple reaction time is the best predictor for table tennis proficiency overall.
Wu et al. [21]	5 continents including 23 countries	87 (56 males, 31 females) international players with ID (M_{Age} 2.69 ± 8.1 years, M_{Play} 11.8 ± 7.3 years, M_{Week}10.4 ± 6.9 h).	Participants were to play using certain types of table tennis skills a few times and to try to make a consistent rally. The player's coach demonstrates a trial and classifiers clearly explain the testing skill to the player. The main types of skills included • Forehand/backhand stroke and rally; • Spin (top, back, and side); • Leg movements—service and attack, high ball attack. The scoring of each skill was defined as • None—wrong stroke and cannot control the ball on the table; • Poor—poor stroke and/or may not consistently control the ball on the table; • Reasonable—reasonable stroke and/or reasonable control of the ball on the table; • Good—good stroke and good control of the ball on the table.	Recommendation of cut-off scores to classify players: ≥60 for service and return service; ≥8 items "good"; ≥3 items "reasonable" for basic skills and control.

Table 3. *Cont.*

Articles	Country/Region	Participants	Protocols	Key Findings
Yam et al. [23]	Singapore	19 male table tennis athletes: 10 wheelchair (classes 1 to 3) players from the Table Tennis Association for the Disabled-Singapore (national level; M_{age} 44.0 to 52.3 years; M_{play} 3.0 to 4.7 years); 9 able-bodied players (M_{age} 23.1 ± 1.6 years; M_{play} 13.4 ± 2.6 years); All trained at least 2 sessions per week.	Players to return balls delivered from a robot. They performed a total of 30 trials (3 sets of 10 consecutive drives) for forehand topspin drives and 30 trials (3 sets of 10 consecutive drives) for backhand topspin drives. Only the trials with projected balls landing diagonally on the lower half of the table within the targeted zone (0.80 m × 0.76 m) were deemed valid. Inertial measurement unit (IMU) sensors were employed to measure upper limb joint angles during forehand topspin and backhand topspin drives: • Shoulder abduction/adduction; • Elbow flexion/extension; • Wrist extension/flexion.	Clear differencesin upper limb kinematics between the able-bodied and wheelchair players, especially in the elbow and wrist. Among para-players, noticeable variations in techniques were also observed between different disability classes.

Data are expressed as mean (standard deviation) unless otherwise stated. DCD denotes developmental coordination disorder; ID denotes intellectual disability; ICC denotes intra-class correlation; IMU denotes inertial measurement unit; IQ denotes intelligent quotient; M denotes mean; M_{Age} denotes mean age; M_{IQ} denotes mean intelligent quotient; M_{play} denotes mean years of playing experience; M_{week} denotes mean number of training hours per week; M_{ST} denotes mean sweep time; NR denotes not reported; SA denotes sweep area; ST denotes sweep time; TD denotes typically developing.

Table 4. Summary of studies (n = 3) assessing functional reach and trunk rotation in individuals with disabilities.

Articles	Country/Region	Participants	Protocols	Key Findings
Lim et al. [24]	Singapore	6 wheelchair para-table tennis players (sex: NR) from the National Table Tennis Team: • Class 1 (n = 3); • Class 2 (n = 3). At least 2 years of international competitive in para-table tennis.	Sweep area (SA)—with shoulders parallel to the table edge, the most superior position of the acromion was then used to position the player, 30 cm away from the table. The players were instructed to draw a perimeter that represented their maximal reach on a piece of paper attached to the table. The perimeter was drawn with a marker attached to their hands. The total reachable area on the table by the player is defined as sweep area (SA).Tipping angle—the players were seated and required to perform a maximal reach to the right and left side along the frontal plane to the point where each player felt that they may fall over from the side. The respective tipping angle is defined as the angle between the player's spine from the seated position to the maximal reach position on the frontal plane. This angle was measured using Kinovea software (version 0.8.15), from videos taken from a camera placed directly behind the players while executing the reach.	Reference data for assessing the movement and ability of para-athletes: • M_{SA} (Class 1: 0.56 ± 0.08 m^2; Class 2: 0.64 ± 0.04 m^2); • Large variation in tipping angles (20° to 49°).
Tang et al. [25]	Singapore	Two male wheelchair para-athletes (Class 1 athlete: lack of triceps and control of muscles beneath the chest level; Class 2 athlete: operate in a motorised wheelchair).	• Sweep area (SA)—total reachable area on a table (see description above in Lim et al. [24]).	Improvement in SA when using the new grip (11.7%, Class 1 athlete) and new Velcro harness with bungee cord (94%, Class 2 athlete).
Zembová et al. [26]	Slovakia	24 male table tennis players (playing > 10 years, competing > 6 years).Wheelchair para-players (n = 11, M_{Age} 36.55 ± 10.31 years): Class 2 (n = 5); Class 3 (n = 3); Class 4 (n = 3). Able-bodied players (n = 13, M_{Age} 37.31 ± 7.76 years).	Trunk rotation angular kinematics were measured on a torso dynamometer. Participants were then required to complete 5 repetitions of trunk rotations to each side, in the seated position with a barbell of 1 kg placed on their shoulders behind the neck. They were instructed to perform trunk rotations with maximal effort in the acceleration phase. They had to engage their core muscles to stiffen the torso and stabilise the spine. Biomechanical variables were analysed: • Angular velocity; • Angular acceleration; • Angular displacement. The trunk rotation from right to left for a right-handed participant was categorised as the "dominant" rotation, whereas the trunk rotation from left to right was referred as the "non-dominant" rotation, and vice versa for a left-handed participant.	No difference between dominant and non-dominant sides ($p > 0.05$) for both groups.All angular kinematics during trunk rotation were significantly lower ($p < 0.05$) in para-table tennis players than able-bodied athletes.

Data are expressed as mean (standard deviation) unless otherwise stated. M denotes mean; M_{Age} denotes mean age; M_{play} denotes mean years of playing experience; M_{week} denotes mean number of training hours per week; NR denotes not reported; SA denotes sweep area; ST denotes sweep time.

3.2. Participant Characteristics

Apart from one study on children aged 7–9 years old [31], all other analysed studies (n = 13, 93%) were conducted on para-table tennis players competing at international and/or national levels (Tables 2–4). These players were well trained and could execute table tennis skills with high precision. Geographically, the studies were conducted in many different regions including Poland (n = 1), Singapore (n = 4), Israel (n = 1), South Africa (n = 1), and Slovakia (n = 1). There are also a few studies collecting data during international competitions, with para-athletes coming from 3 to 5 continents including 15 to 23 countries [5,6,8,10]. No included studies have examined the proficiency in recreational players or those who compete at a lower level (e.g., clubs, schools).

3.3. Types of Disabilities

Many studies (n = 8, 57%) examined high-level players with intellectual disabilities [16–20]. These para-athletes were competing at Special Olympics and/or International Sports Federation for Persons with Intellectual Disability (INAS-FID) World Championships. For para-athletes with physical disabilities, they can compete in wheelchairs (Classes 1 to 5) or while standing (Classes 6–10). In the 14 studies analysed, 5 studies included wheelchair athletes across classifications—Class 1 (n = 3), Class 2 (n = 4), Class 3 (n = 2), Class 4 (n = 1), and Integrated Classes 1–5 (n = 1) [23–27]. Only two studies have been conducted on standing players, comprising a case study on a Class 7 male para-athlete with severe leg impairment [22], and a study that combined 10 players from Classes 6–10 into a single group [27]. Lastly, one study [31] implemented an active video games intervention on children with DCD, a neuro-developmental disorder that affects the development of movement and coordination skills.

3.4. Table Tennis-Specific Tests

Based on the study by Wu et al. [21], the table tennis-specific test protocols were categorised into accuracy (n = 5), skill and control (n = 9), and others (n = 3). Several studies used a table tennis robot (n = 6) and/or a video camera (n = 7) to facilitate the conduct and scoring of the tests (Figure 2b).

Accuracy assessments include service, return service/stroke, and throw-and-catch accuracies. Depending on where the ball lands on the table, a score (e.g., 0–2, 1–5) is typically assigned to reflect the accuracy of the trial [21,27]. Using video recording, one study performed a more detailed analysis by quantifying the magnitude and direction of the error from the target [16]. In the study by Smits-Engelsman et al. [31] who used a “Cup Ping-Pong” game to assess the accuracy of throwing and catching a table tennis ball, the total number of balls caught out of 10 trials was counted.

In the category of skill and control assessment in table tennis, participants were asked to return serves delivered by a robot using a prescribed stroke to specific areas of the opposite side of the table [17,18,22,23]. A wide variety of strokes have been examined, such as forehand and backhand drives with various spins and directions. Instead of using a robot, there are also studies in which participants played rallies against a human opponent and were instructed to “try to win each rally” [19,20]. The quality of the strokes can be rated via scoring [21] or expert observations using pre-determined protocols [17–20]. Others used inertial measurement unit (IMU) sensors to assess the upper limb movement pattern via biomechanical analysis [22,23]. A study conducted by Lim et al. [24] aimed to evaluate the manoeuvrability of wheelchair players within their functional reach range. In this test, six balls were placed at designated locations on a table, propped up to a height of 40 mm. The objective was for the player to hit these balls to the opposite side on the table and the time taken to complete the task is termed “sweep time”.

Lastly, several additional measures of functional reach or trunk rotation characteristics were specific to table tennis. Two studies [24,25] involving wheelchair players employed the concept of “sweep area”, which refers to the total reachable area on a table. The players were seated 30 cm from the centre of the table, drawing a perimeter that represented their maximum reach on a piece of paper attached to the table. The quantification of the encompassed area in the drawing was called “sweep area”. Lim et al. [24] also used video analysis to measure the “tipping angle”, which represented the angle of the spine at maximum left or right lean when seated. As trunk rotation is important for generating speed in table tennis strokes, one study [26] employed a specialised torso dynamometer to examine the angular kinematics when wheelchair para-players forcefully rotated their trunk to the left and right sides.

4. Discussion

This comprehensive overview summarised the current test protocols for assessing table tennis technical proficiency in individuals with disabilities into three categories, namely accuracy, skill and control, and functional reach and trunk rotation. Almost all included studies were conducted on well-trained para-athletes competing in high-level competitions under different disability classifications including wheelchair, standing, and ID.

4.1. Table Tennis Technical Proficiency Tests

4.1.1. Accuracy

For service accuracy, Galas et al. [27] developed detailed protocols for short service, extreme side service, and target service. With consideration of the type of disabilities, they set the target zones according to the player’s classification as wheelchair or standing players. The authors provided very clear drawings and descriptions of the test instructions, number of attempts, and scoring methods. Similarly, Wu et al. [21] also utilised a series of tests to assess the accuracy of various services (long backspin to backhand/forehand, short backspin to backhand, long no spin to body, fast ball to forehand, and long sidespin to backhand). A score of 0 to 2 was assigned depending on the service execution (wrong service/poor control/good control) and landing location of the ball (missed/poor location/good location). However, no further information was provided on what is considered good control or good location. The table tennis experience and number of raters involved in assigning the scores were not reported. Hence, it is somehow difficult to replicate these tests and to compare the results across studies. One common strength shared by all service accuracy test protocols is that no specialised equipment is required. To implement service accuracy tests; only a simple video camera or mobile phone would be sufficient to record where the ball hits the table.

For service return and stroke accuracy, some tests were first developed for able-bodied players and subsequently applied to individuals with disabilities. For example, Galas et al. [27] employed the forehand/backhand skill speed tests and displacement speed test previously evaluated in able-bodied players [32] with elite para-players with physical and intellectual disabilities. In these tests, table tennis balls were shot by a robot at high speed with 80 balls per minute to different locations. Players were instructed to return the shots using specific techniques (e.g., topspin forehand, topspin backhand) to designated areas across the table. Similarly, Van Biesen et al. [16] developed a comprehensive protocol comparing 16 set services of various strokes (forehand/backhand), directions of return (cross/straight), spins (topspin/backspin/right sidespin/left sidespin), and fields of return (left/right side of the table). Using a table tennis robot to deliver shots at a frequency of 1 ball every 2 s, players were instructed to return each service to a specified target (A4 paper size) on the table. From video recordings of the service return, a 7-by-7 digital frame was constructed around the target to calculate the relative error as width (left–right) and depth (forward–backward) deviations from the target. A deviation of one square in the 7-by-7 frame was counted as 1 point in the respective direction. This data analysis method allows one to quantify the magnitude and direction of the error, providing additional insights than using a simpler scoring system such as hit or miss.

Lastly, Smits-Engelsman et al. [31] used a “Cup Ping-Pong” protocol to assess the accuracy of throwing and catching in children with DCD. The children were instructed to throw a table tennis ball against the wall at 1 m distance and catch it in a plastic beer cup in the other hand.

The number of balls caught out of 10 attempts was counted. This test is simple and easy to implement, making it a good choice for field testing. As the throwing and catching protocol only involves ball manipulation without the use of a racket, it is unclear if the scores can indicate table tennis performance or more general hand–eye coordination. Ball manipulation and hand–eye coordination are deemed relevant to table tennis because a legal serve requires players to toss the ball up for at least 16 cm (6.3 inches) before hitting the ball on its way down. If similar throw-and-catch tests are to be implemented for players with physical disabilities, some adaptations may be needed to adjust the rebound distance and how the ball is being caught. For example, a distance of 1 m between the player and the wall may be too short for adult para-athletes with high functional abilities. Individuals with a missing hand cannot hold a cup to receive the ball and therefore alternative catching strategies are required.

4.1.2. Skill and Control

The majority of the included studies (*n* = 9, 64%) incorporated test protocols to assess the table tennis-specific skills and ball control. We adopted the term "skill and control" proposed by Wu et al. [21] in their study aiming to classify para-players with ID using table tennis-specific tests. Broadly speaking, this category reflects a player's ability to effectively return services and effectively execute table tennis strokes with a good control of ball spin and direction of travel. Participants may play against a human opponent [19,20] or receive shots delivered by a table tennis robot [17,18,22,23] while their movements were being assessed. Some studies, however, did not specify how the table tennis performance data were collected [21,30].

Many different types of table tennis strokes have been included in the skill assessment protocols, of which the forehand topspin and backhand topspin have been examined the most [18,21–23]. Other skills such as contra, push, block, flick, smash, serve and attack, and high ball attack have also been tested. Some tests required players to return the ball to the opposite side of the table [18] or diagonally on the lower half of the table within a targeted zone of 0.80 m $\times$ 0.76 m [22,23], while others did not specify the landing area [21]. Previous studies using a robot to deliver shots typically used fast speeds (speed > 30 mph for push, flick, and smash) and high frequencies (34.5 to 43 balls per min) because the tested participants were well-trained competitive para-table tennis athletes [16,17]. It is important to note that these test protocols and robot settings may not be suitable for players with a lower proficiency level. For beginners and recreational para-table tennis players, it is recommended to use a slower ball speed with fewer balls per minute. The difficulty of the tests should also be adjusted as lower-proficiency players may not be able to execute a wide variety of strokes and counter different types of spin.

There exist different approaches to assess the effectiveness and/or quality of table tennis strokes. For instance, some studies developed a technical observation protocol to rate each stroke criterion as 1 (the criterion was clearly observable) or 0 (the criterion was not observable or incompletely executed) [17,18,20]. Another study classified each stroke as none, poor, reasonable, or good [21]. Others used biomechanical equipment to quantify the joint movement patterns and range of motion [22,23]. Given that only limited studies have been published in this area, there is currently no consensus or standardised scoring methods to differentiate different levels of skills and control in para-table tennis players. In general, the current practice relies more heavily on expert ratings than quantitative measurements determined from biomechanical instrumentation.

4.1.3. Functional Reach and Trunk Rotation

Two studies in Singapore used "sweep area" to measure wheelchair para-players' maximum functional reach on the table [24,25]. This method is easy to implement using simple pen and paper, though additional time is required to calculate the area from the drawings after data collection. It is important to standardise the distance between the player and the table, which was 30 cm in both studies. Using the "sweep area" as a variable to indicate functional reach ability, promising results with 11.7% to 94.0% improvement were noted when implementing a customised design modification to the player's wheelchair. Another variable called "tipping angle" has been used to measure the functional reach to the left and right side along the frontal plane [24]. In this study, wheelchair players were asked to reach as far as possible to the point where they felt that they may fall over from the side. The angle of the spine in this maximum reach position was measured using the Kinovea video analysis software (version 0.8.15), though it was not specified how the line of spine was identified. It can be challenging to precisely and consistently locate the body landmarks to define the torso segment, especially for individuals with abnormal curvatures in the spine [33]. Taken together, measuring functional reach ability is a relevant and feasible assessment protocol for para-tennis players. As this concept has only been applied to wheelchair athletes so far using area and/or angle variables which require the additional post-processing of data, future work can explore simpler and direct measures such as reach distances to different directions. It will be of interest to see if the functional reach test is also useful for standing players.

For one-handed strokes in racket sports, lumbar spine axial rotation is important as it can influence upper limb movements and racket speed [34]. To examine the rotational function of the trunk in wheelchair para-table tennis players, Zemková and colleagues [26] used a torso dynamometer to determine angular acceleration, velocity, and displacement. Considering the nature of table tennis which relies heavily on one arm, it is somewhat surprising to observe no differences in trunk angular kinematics between the dominant and non-dominant sides. Compared with able-bodied players, this study showed a slower trunk rotation velocity in para-players, which might be due to their limited range of motion in the trunk. While this assessment protocol provided robust and objective measures to evaluate players' trunk function, the need for specialised laboratory equipment to implement the test and biomechanical knowledge to interpret the data may impose challenges for practitioners and clinicians. At present, no studies have examined the trunk rotation movement during the execution of actual table tennis skills in individual with disabilities. The limited biomechanics studies on para-table tennis strokes only focused on the shoulder, elbow, and/or the wrist [22,23].

4.2. Validity and Reliability

Only a few studies have addressed the validity and/or reliability of the table tennis test protocols applied to individuals with disabilities. Van Biesen at al. [17] demonstrated that their technical proficiency tests had good inter-rater and intra-rater reliability and were able to distinguish between players with (total score 63.7 $\pm$ 12.5%) and without ID (total score 87.6% $\pm$ 6.2%). The authors assessed the content validity of the technical proficiency tests through discussion with expert table tennis coaches and players. They explained that face validity was difficult to assess because there was no gold standard available to compare against. In a study on able-bodied table tennis players, the concurrent validity of the "Dutch motor skills assessment" protocol was examined from the associations between the assessment results and the players' national ranking; boys $r = -0.53$ ($p < 0.001$) and girls $r = -0.45$ ($p = 0.015$) [14].

Galas et al. [27] established the test–retest reliability and face validity of para-table tennis-specific accuracy and prevision tests. Face validity was assessed by asking high-level para-table tennis coaches to review the measurement techniques and evaluate their suitability using guided questions (e.g., Were the components of the measure relevant to what is being measured?). The authors reported a high level of agreement among the raters who all agreed that the test measures were what they intended to measure, providing good evidence for face validity (i.e., Cohen's Kappa coefficient, ranging from 0.80 to 0.93). The reliability over three test sessions was varied (ICC ranging from 0.252 to 0.661) but overall sufficient. However, their test results were not correlated with world rankings, possibly due to the small sample size ($n = 23$) and the fact that all participants were of a high competency level.

Lastly, Inbal et al. [30] reported a high internal consistency between items within 4 types of table tennis-related skill tests, namely balance, hand–eye coordination, power regulation, and motor coordination. There were, however, no details of the individual items. The authors briefly mentioned that the tests were validated by 11 experts in special education, physical education, and table tennis, but it was not explained how this was done. The test–retest reliability of the test protocols was not assessed.

4.3. Practical Implications

Coaches and sports scientists can consider adopting some previously developed protocol to test their players' table tennis proficiency and monitor their training progress. Service accuracy can be easily assessed by asking players to serve using a specific technique to a pre-set target on the opposite end of the table. Simple methods such as placing a piece of paper or drawing lines on the table are sufficient to define the target area. Scoring can be performed quickly based on where the ball lands on the table. A video camera or mobile phone can also be used to record the test and further quantify the magnitude of the error (i.e., how far away the ball is from the target) using software such as Dartfish and Kinovea. Return accuracy and the quality of the strokes are more difficult to assess, and this require the players to return balls delivered by a table tennis robot or play against a human opponent who can serve and play consistently. The quality of table tennis skills can be evaluated by expert rating (e.g., an experienced coach) using pre-determined criteria (see examples in Table 3). This can be performed via live observation or from video recordings. If access to equipment and expertise are available, comprehensive biomechanical analysis can be performed to quantify the movement characteristics at different joints.

4.4. Future Directions

Currently, almost all table tennis technical proficiency tests were developed for well-trained competitive para-table tennis players. These tests are likely to be too difficult for less proficient players and hence direct adoption of the protocol set-up (e.g., ball speeds and frequency fed from a robot) is not recommended. There is a need to construct assessment protocols for players across all competency levels, including beginners, reactional players, and those competing at different levels (e.g., school, clubs, university, national, international). Ideally, the tests should cater for different types of disabilities such as wheelchair players, standing players, and those with ID.

In the literature, there is no consensus on how to assess the quality of para-table tennis skills and ball control. For example, what is considered a good topspin forehand drive for a wheelchair player? The inconsistency in expert opinion and scoring scales (e.g., 0/1, 0–2, 1–5) makes it extremely difficult if not impossible to compare across studies. Future assessment protocols should clearly describe the skill criteria and scoring methods to allow standardisation across different table tennis communities. As the desirable skill characteristics will vary across the different types of disabilities, the protocols should be carefully designed with expert inputs from para-coaches, para-athletes, sports scientists, and medical professionals. With a consistent protocol and scoring system, reference norms with respect to different types of disabilities and playing levels can be established.

The validity and reliability of the test protocols should be rigorously addressed in the future. It is critical that the test items reflect what they intended to measure, and with good test–retest reliability over multiple sessions. If the protocol involves expert observation and scoring, the inter-rater and intra-rater reliabilities should also be established. For a test protocol to be practically meaningful, the outcome measures should be able to differentiate between skill levels, and to detect changes over time for monitoring learning progress and training status [35].

Although many studies used a video camera to record the players' movement and ball trajectory, the video recordings were mostly limited to basic applications such as counting the number of trials landing in the target zone and scoring the quality of the strokes based on expert observations. Some studies used video analysis software such as Dartfish [16] and Kinovea [24] to manually perform simple two-dimensional position or angle analysis. With the recent advancement in artificial intelligence (AI) in sports, there is a lot of potential to maximise the use of video recordings of para-table tennis movements. For instance, Goh et al. [36] successfully used computer vision and machine learning methods to automatically detect service faults in badminton. Their new method outperformed human judges by a factor of 3.5, leading to a substantial enhancement in the accuracy rate for service fault detection. Moving forward, AI should replace human observation to identify the landing locations of the table tennis balls and to quantify the magnitude and direction of the errors. For the player's movement characteristics, pose estimation algorithms can be leveraged to identify body landmarks from videos and to calculate three-dimensional kinematics of different joints [13,37,38]. Such AI-driven approaches can provide rich and objective information on the table tennis movement, complementing the qualitative assessment typically performed by expert coaches.

4.5. Limitations

There are several limitations of this study. Firstly, only 14 studies were included in this review. This small number may be related to the search strategy which was limited to English articles within four databases typically used for sport-related research studies. We may have missed some reports that were not published in English or academic databases. For example, athletes from the Republic of Korea excelled in the 2022 World Para-Table Tennis Championships, winning 10 out of 39 events. In the Tokyo 2020 Paralympic Games, China won gold in all five table tennis team events. In the current review, no studies were specifically conducted in Korea or China despite their high international standing in para-table tennis. There may exist other test protocols that were written in non-English languages such as Korean and Chinese. Secondly, this review lacks critical appraisal to indicate the quality of the included studies. Unlike systematic reviews and meta-analyses, critical appraisal is not mandatory for scoping reviews. We acknowledge that some studies included in the present review were not sufficiently well organised, lacking details in the methodology, and could be difficult to understand. The lack of reliability and validity checks in most studies further calls into question the robustness and effectiveness of the table tennis test protocols. Fourthly, only 6 out of 14 studies were published within the past 5 years. As such, the protocols summarised in this review may not represent the current practice and recent advancement in the field. Lastly, we arbitrability grouped the assessment protocols into three categories (accuracy, skill and control, others) based on Wu at al. [21]. As the movement pattern and task outcome are closely related, it may not be appropriate to disassociate the accuracy and skill components of a task.

5. Conclusions

This scoping review summarised the current test protocols for assessing the table tennis technical proficiency in individuals with disabilities. A total of 14 studies were included, covering various types of physical and intellectual disabilities. There exist protocols to assess the service and stroke accuracy, hand–eye coordination, quality of specific skills and ball control, functional reach, and torso rotation. In terms of skills, the forehand topspin and backhand topspin drives were tested the most. Pertaining to test equipment, a considerable number of studies used table tennis robots or video cameras to facilitate the conduct and scoring of the tests. As almost all previous work targeted well-trained para-athletes competing at a high level, more attention should be paid to developing technical proficiency tests that are also suitable for players with lower competency levels. The skill assessment criteria and scoring methods in the tests should be standardised and clearly explained to facilitate comparison across players and the establishment of reference norms. The validity and reliability of previous test protocols were inadequately addressed in the literature, calling for more robust research in this area. Lastly, there is great potential in the use of AI and technology to enhance the speed, accuracy, and quality of the table tennis assessment protocols in individuals with disabilities.

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References

1. Krahn, G.L. WHO World report on disability: A review. *Disabil. Health J.* **2011**, *4*, 141–142. [CrossRef] [PubMed]
2. Brown, D.R.; Carroll, D.D.; Workman, L.M.; Carlson, S.A.; Brown, D.W. Physical activity and health-related quality of life: US adults with and without limitations. *Qual. Life Res.* **2014**, *23*, 2673–2680. [CrossRef]
3. Rinaldi, R.G.; Manin, L.; Moineau, S.; Havard, N. Table tennis ball impacting racket polymeric coatings: Experiments and modeling of key performance metrics. *Appl. Sci.* **2019**, *9*, 158. [CrossRef]
4. Malagoli, L.I.; Bartolomei, S.; Di Michele, R.; Gu, Y.; Baker, J.S.; Fantozzi, S.; Cortesi, M. Kinematic analysis of the racket position during the table tennis top spin forehand stroke. *Appl. Sci.* **2021**, *11*, 5178. [CrossRef]
5. Schneider, R.; Lewerentz, L.; Lüskow, K.; Marschall, M.; Kemnitz, S. Statistical analysis of table-tennis ball trajectories. *Appl. Sci.* **2018**, *8*, 2595. [CrossRef]
6. Pradas, F.; de la Torre, A.; Carrasco, L.; Muñoz, D.; Courel-Ibáñez, J.; González-Jurado, J.A. Anthropometric profiles in table tennis players: Analysis of sex, age, and ranking. *Appl. Sci.* **2021**, *11*, 876. [CrossRef]
7. Li, X. Biomechanical analysis of different footwork foot movements in table tennis. *Comp. Intell. Neurosci.* **2022**, *10*, 9684535. [CrossRef]
8. He, Y.; Fekete, G.; Sun, D.; Baker, J.S.; Shao, S.; Gu, Y. Lower limb biomechanics during the topspin forehand in table tennis: A systemic review. *Bioengineering* **2022**, *9*, 336. [CrossRef]
9. Lam, W.K.; Fan, K.X.; Zheng, Y.; Lee, W.C.C. Joint and plantar loading in table tennis topspin forehand with different footwork. *Eur. J. Sport Sci.* **2019**, *19*, 471–479. [CrossRef]
10. Mao, C.; Liu, T.; Li, X.; Lu, Z.; Li, Z.; Xing, K.; Chen, L.; Sun, Y. A Comparative Biomechanical Analysis of Topspin Forehand against Topspin and Backspin in Table Tennis. *Appl. Sci.* **2023**, *13*, 8119. [CrossRef]
11. Xing, K.; Hang, L.; Lu, Z.; Mao, C.; Kang, D.; Yang, C.; Sun, Y. Biomechanical comparison between down-the-line and cross-court topspin backhand in competitive table tennis. *Int. J. Environ. Res. Public Health* **2022**, *19*, 5146. [CrossRef]
12. Haas, F.; Baumgartner, T.; Klein-Soetebier, T.; Seifriz, F.; Klatt, S. Heatmap analysis to differentiate diverse player types in table tennis—A training and tactical strategy development potential. *Appl. Sci.* **2023**, *13*, 1139. [CrossRef]
13. Wu, C.H.; Wu, T.C.; Lin, W.B. Exploration of applying pose estimation techniques in table tennis. *Appl. Sci.* **2023**, *13*, 1896. [CrossRef]
14. Faber, I.R.; Nijhuis-Van Der Sanden, M.W.; Elferink-Gemser, M.T.; Oosterveld, F.G. The Dutch motor skills assessment as tool for talent development in table tennis: A reproducibility and validity study. *J. Sports Sci.* **2015**, *33*, 1149–1158. [CrossRef]
15. Faber, I.R.; Koopmann, T.; Schipper-van Veldhoven, N.; Twisk, J.; Pion, J. Can perceptuo-motor skills outcomes predict future competition participation/drop-out and competition performance in youth table tennis players? A 9-year follow-up study. *PLoS ONE* **2023**, *10*, e0281731. [CrossRef]
16. Van Biesen, D.; Verellen, J.; Meyer, C.; Mactavish, J.; Van de Vliet, P.; Vanlandewijck, Y. The ability of elite table tennis players with intellectual disabilities to adapt their service/return. *Adapt. Phys. Act. Q.* **2010**, *27*, 242–257. [CrossRef] [PubMed]
17. Van Biesen, D.; Mactavish, J.; Pattyn, N.; Vanlandewijck, Y.C. Technical proficiency among table tennis players with and without intellectual disabilities. *Hum. Mov. Sci.* **2012**, *31*, 1517–1528. [CrossRef] [PubMed]
18. Van Biesen, D.; Mactavish, J.; Vanlandewijck, Y.C. Comparing technical proficiency of elite table tennis players with intellectual disability: Simulation testing versus game play. *Percept. Mot. Skills* **2014**, *118*, 608–621. [CrossRef]
19. Van Biesen, D.; Mactavish, J.; Vanlandewijck, Y.C. Tactical proficiency among table tennis players with and without intellectual disabilities. *Eur. J. Sport Sci.* **2014**, *14*, 403–409. [CrossRef]
20. Van Biesen, D.; Mactavish, J.; Kerremans, J.; Vanlandewijck, Y.C. Cognitive predictors of performance in well-trained table tennis players with intellectual disability. *Adapt. Phys. Act. Q.* **2016**, *33*, 324–337. [CrossRef]
21. Wu, S.K.; Li, Y.C.; Chang, Y.C.; Wu, K.C. Analysis of the table tennis specific test in classification for players with an intellectual disability. *Glob. J. Intellect. Dev. Disabil.* **2021**, *9*, 555764. [CrossRef]

22. Kong, P.W.; Yam, J.W. Shoulder biomechanics of para-table tennis: A case study of a standing class para-athlete with severe leg impairment. *BMC Sports Sci. Med. Rehabil.* **2022**, *14*, 143. [CrossRef] [PubMed]
23. Yam, J.W.; Pan, J.W.; Kong, P.W. Measuring upper limb kinematics of forehand and backhand topspin drives with IMU sensors in wheelchair and able-bodied table tennis players. *Sensors* **2021**, *21*, 8303. [CrossRef]
24. Lim, D.; Yap, W.B.; Tan, Z.; Li, H.; Teng, P. A case study of para table tennis athlete's functional ability. In Proceedings of the 3rd International Congress on Sport Sciences Research and Technology Support, Lisbon, Portugal, 15–17 November 2015; Volume 1, pp. 167–173.
25. Tang, S.Q.; Li, K.H.H.; Lim, S.L.D. Design enhancement of overall Paralympics wheelchair for para table tennis competition. Proceedings of the Institution of Mechanical Engineers, Part P. *J. Sports Eng. Technol.* **2019**, *233*, 342–350. [CrossRef]
26. Zemková, E.; Muyor, J.M.; Jeleň, M. Association of trunk rotational velocity with spine mobility and curvatures in para table tennis players. *Int. J. Sports Med.* **2018**, *39*, 1055–1062. [CrossRef] [PubMed]
27. Galas, S.; Andrzejewski, M.; Pluta, B. Reliability of accuracy and precision tests for elite para table tennis players. *Adapt. Phys. Act. Q.* **2023**, *41*, 268–286. [CrossRef] [PubMed]
28. Wong, D.W.C.; Lee, W.C.C.; Lam, W.K. Biomechanics of table tennis: A systematic scoping review of playing levels and maneuvers. *Appl. Sci.* **2020**, *10*, 5203. [CrossRef]
29. Saaiq, M.; Ashraf, B. Modifying "Pico" question into "Picos" model for more robust and reproducible presentation of the methodology employed in a scientific study. *World J. Plast. Surg.* **2017**, *6*, 390. [PubMed]
30. Inbal, B.; Grous, E.; Grous, V. How to increase the performance in Special Olimpics table tennis players. *J. Phys. Act.* **2016**, *5*, 28–45.
31. Smits-Engelsman, B.C.; Bonney, E.; Jelsma, D. Task-specificity and transfer of skills in school-aged children with and without developmental coordination disorder. *Res. Dev. Disabil.* **2023**, *133*, 104399. [CrossRef]
32. Katsikadelis, M.; Pilianidis, T.; Mantzouranis, N. Test-retest reliability of the table tennis specific battery test in competitive level young players. *Eur. Psychomot. J.* **2014**, *6*, 3–13.
33. Furlanetto, T.S.; Sedrez, J.A.; Candotti, C.T.; Loss, J.F. Photogrammetry as a tool for the postural evaluation of the spine: A systematic review. *World J. Orthop.* **2016**, *7*, 136–148. [CrossRef] [PubMed]
34. Kawasaki, S.; Imai, S.; Inaoka, H.; Masuda, T.; Ishida, A.; Okawa, A.; Shinomiya, K. The lower lumbar spine moment and the axial rotational motion of a body during one-handed and double-handed backhand stroke in tennis. *Int. J. Sports Med.* **2005**, *26*, 617–621. [CrossRef] [PubMed]
35. Khong, S.W.J.; Kong, P.W. A simple and objective method for analyzing a gymnastic skill. *Eur. J. Phys. Educ. Sport* **2016**, *12*, 46–57. [CrossRef]
36. Goh, G.L.; Goh, G.D.; Pan, J.W.; Teng, P.S.P.; Kong, P.W. Automated Service Height Fault Detection Using Computer Vision and Machine Learning for Badminton Matches. *Sensors* **2023**, *23*, 9759. [CrossRef] [PubMed]
37. Uhlrich, S.D.; Falisse, A.; Kidziński, Ł.; Muccini, J.; Ko, M.; Chaudhari, A.S.; Hicks, J.L.; Delp, S.L. OpenCap: Human movement dynamics from smartphone videos. *PLoS Comput. Biol.* **2023**, *19*, e1011462. [CrossRef]
38. Lafayette, T.B.d.G.; Kunst, V.H.d.L.; Melo, P.V.d.S.; Guedes, P.D.O.; Teixeira, J.M.X.N.; Vasconcelos, C.R.D.; Teichrieb, V.; da Gama, A.E.F. Validation of angle estimation based on body tracking data from RGB-D and RGB cameras for biomechanical assessment. *Sensors* **2023**, *23*, 3. [CrossRef]