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The physical demands of wheelchair tennis match play: protocol for a systematic review and meta-analysis

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Review question / Objective: **Our aim was to describe and synthesise the physical demands of wheelchair tennis. We reviewed the data across different playing surfaces, performance levels and sex of tennis players. Review question(s) 1. What are the characteristics of the physical demands of singles and doubles wheelchair tennis match play of different sex, sport classes and performance levels? 2. How do physical demands differ for age-category (junior, senior) and court surface (hard court, clay court, and grass court)?**
Eligibility criteria: **Studies had to meet the criteria below to be included in the review:i. The paper reported on participants playing singles or doubles wheelchair tennis matches (all ages, performance levels, quad or open category and court surfaces).ii. The data collected was related to the duration of play (e.g. length of match, effective playing time), on-court movement characteristics (e.g. distance covered, moving speed, accelerations), stroke characteristics (e.g. first serve %, count, frequency) or physiological response to match play (e.g. heart rate, oxygen uptake, energy expenditure) of wheelchair tennis.**

INPLASY registration number: This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 17 March 2023 and was last updated on 06 April 2023 (registration number INPLASY202330060).

INTRODUCTION

Review question / Objective: **Our aim was to describe and synthesise the physical demands of wheelchair tennis. We reviewed the data across different playing surfaces, performance levels and sex of tennis players. Review question(s) 1. What are the characteristics of the physical demands of singles and doubles wheelchair tennis match play of different sex, sport classes and performance levels?**

2. How do physical demands differ for age-category (junior, senior) and court surface (hard court, clay court, and grass court)?

Rationale: Wheelchair tennis, the para sport version of tennis, is aimed at individuals with a physical impairment and can be defined as playing tennis in a seated position. Wheelchair tennis has the same rules as standing tennis, except the ball can bounce twice. Wheelchair tennis is played at both a professional level, and recreationally, as an inclusive sport with possible mixing with standing players. Matches can take place on the same surfaces as standing tennis (mainly hard courts, clay and grass). Wheelchair tennis has two sport classes: the Open division is for players with a permanent impairment in their lower extremities, and the Quad division is for players with additional impairments in their upper extremities, limiting their ability to handle the racket and manoeuvre the wheelchair. More than 100 countries play the sport and the ITF wheelchair tennis tour has over 150 events. Tactical, technical, physical and psychological skills are required to compete at a high level in wheelchair tennis. As the sport continues to develop, the physical attributes required at the elite level are increasingly demanding and important. The physical capacities needed to perform all activities of wheelchair tennis are wide-ranging, including but not limited to strength, power, and aerobic endurance.
To best prepare and develop players and to monitor the progression of this relatively new professional sport, a thorough understanding of the physical demands of wheelchair tennis is essential. The physical demands of standing tennis have recently been published[1], but the authors are unaware of any review of the published literature examining the physical demands of wheelchair tennis. This systematic review aims to summarise the physical demands of singles and doubles wheelchair tennis across the different sport classes, ages, performance levels, and sex of the players on various court surfaces by reviewing the scientific literature on this topic.

Condition being studied: The physical demands during wheelchair tennis match play, focusing on activity demands (time characteristics, wheelchair mobility, and stroke performance) rather than physiological load or biomechanical characteristics.

METHODS

Search strategy: A comprehensive search will be performed in the bibliographic databases PubMed, Embase.com, CINAHL (via Ebsco) and SPORTDiscus (via Ebsco) from inception to March 1, 2023, in collaboration with a medical librarian (LS). Search terms will include controlled terms (MeSH in PubMed and Emtree in Embase, CINAHL Headings in CINAHL and Thesaurus terms in SPORTDiscus) as well as free text terms. The following terms (including synonyms and closely related words) will be used as index terms or free-text words: 'wheelchair' and 'tennis'. The search will be performed without date or language restrictions. Duplicate articles will be excluded by a medical information specialist (LS) using Endnote X20.5 (Clarivatetm), following the Amsterdam Efficient Deduplication (AED)-method [2] and the Bramer-method [3]. Additionally, a backward citation search will be conducted for included articles using Scopus.

Participant or population: Wheelchair tennis players of all ages, sport classes (Open and Quad), and playing levels (regional, national, international).

Exposure: Wheelchair tennis match play according to International Tennis Federation (ITF) rules.

Comparator: N/A.

Study designs to be included: Descriptive cross-sectional studies, analytic observational prospective and retrospective cohort studies; intervention studies (baseline data will be included only).

Eligibility criteria: The PECOS (Population, Exposure, Comparison, Outcome, and

Study design) framework was used to define inclusion and exclusion criteria.
Inclusion criteria
i) Population: Male and female wheelchair tennis players of regional, national, or international playing level; juniors (≤ 18 years) and adults;
ii) Exposure: Singles and doubles wheelchair tennis match play according to the International Tennis Federation (ITF) rules;
iii) Comparison: none
iv) Outcome: Reports at least one parameter related to the duration of play (e.g., strokes, rallies, games, sets, and matches), wheelchair mobility (e.g., accelerations, decelerations, rotations, distance covered, and movement speed), stroke performance (count and speed), or physiological variables (e.g., heart rate, oxugen uptake, and energy expenditure;
v) Study designs: Descriptive cross-sectional studies, analytic observational prospective and retrospective cohort studies; randomised and non-randomised intervention studies (baseline data only).
Exclusion criteria:
i) Editorials, notes, letters, case reports, and reviews;
ii) Studies of wheelchair tennis during match play with modified rules (e.g., time-capped matches);
iii) Studies of standing (able-bodied) tennis;
iv) Studies reporting biomechanical variables only.

Information sources: A systematic literature search was performed in the bibliographic databases Medline, Embase and Web of Science from inception to 12th January 2023.

Main outcome(s): We will analyse the activity demands related to the duration of play, wheelchair movement and player strokes by reviewing observational and analytic studies. We will compare the demands of male and female players at different levels of play and on different court surfaces.
We will focus on the outcomes related to these areas:
Time characteristics: strokes, points (rallies), sets, games, and matches.
Wheelchair mobility: accelerations, decelerations, rotations, distance covered and average and peak wheelchair speed.
Stroke performance: type and number
Physiological variables: heart rate, oxygen uptake, and energy exenditure.

Data management: Reviewer SM extracted data related to the following characteristic from each of the appropriate studies. This was double-checked by NH. Characteristics included; name of first author, year of publication, location of study, study design and aim, population, sample size, age, sex, performance level, assessment tool, overview of outcome measures. Data related to the outcome measures was extracted for later analysis.
i. Duration: match duration expressed in minutes, rally duration expressed in seconds and number of strokes, effective playing time as a percentage of total time, work-to-rest ratio defined as the ratio between rally duration and rest periods between rallies, points per game/set/match were expressed by numbers, games per set/match were expressed by numbers and sets per match were expressed by numbers.
ii. On- court Movement characteristics: acceleration and deceleration expressed in m/s2, changes in direction expressed as number per match or rally, distance covered expressed in metres per point/game/set/match/minute/hour and peak moving speeds expressed in m/s.
iii. Stroke characteristics: stroke counts expressed as a number per/game/set/match/second, stroke speed expressed in km/h and type of stroke was subdivided into forehands, backhands, serves, volleys and overheads and were expressed as numbers.
iv. Physiological Variables: peak heart rate and average heart rate expressed in bpm, oxygen uptake expressed as ml/kg/min and energy expenditure expressed in kcal.

Quality assessment / Risk of bias analysis: Reviewers SM and NH independently assessed the methodological quality of all appropriate studies using the Joanna Briggs Institute Checklist for Analytical Cross-Sectional Studies. SM and NH

discussed any unclear questions until a consensus was reached and a third reviewer was available for any disputes. This assessment was not used to determine study inclusion or perform sub-group analysis based on methodological quality due to risk of bias.

Strategy of data synthesis: The outcomes were analysed based on overall categorises as follows:
i. Sex
ii. Open vs Quad category
iii. Single vs doubles match
iv. Performance levels
v. Playing surface
For quantitative statistical analysis, mean differences were calculated and confidence intervals were set to 95% to determine significance.
Qualitative Synthesis
The descriptive characteristics of each study were summarised. A table comprised of this information can be found in the appendix.

Subgroup analysis: Planned subgroup analysis with study variables in the following subgroups: male and female; international, national, and regional level players; open and quad division, and juniors and adults.

Sensitivity analysis: Sensitivity analysis is planned on the results.

Language restriction: Papers need to be available in English.

Country(ies) involved: UK.

Keywords: Tennis; wheelchair; physical demands.

Dissemination plans: Appropriate publications and presentation of data as well as sharing the results with relevant tennis bodies.

Other relevant information:
Selection process
The study selection process will be reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart [4]. Two reviewers will independently screen all titles and abstracts for eligibility using Rayyan [5]. The full text article will be checked for eligibility criteria if deemed appropriate. Differences in judgement will be resolved through discussion until consensus has been reached. An independent reviewer will be available to make a final decision if the reviewers cannot reach consensus. Reasons for exclusion will be documented at each stage.
Risk of bias (quality) assessment
Two reviewers will independently evaluate the methodological quality of the full text papers using the Johanna Briggs Institute Checklist for analytical cross-sectional studies [6]. Differences in judgement will be resolved through consensus discussion or a third reviewer if consensus can not be reached. The quality assessment outcome will not be used to determine study inclusion. We will not perform sub-group analysis based on the methodological quality/risk of bias.
Data Synthesis
The outcomes will be analysed based on three overall categories: “male”, “female”, and “male vs female”. The analysis will be stratified based on experience level, “regional”, “national” or “international”, to ensure reasonable (statistical) homogeneity of the studies. We will also differentiate between the sport classes, “Open division” and “Quad division”, age-categories, “juniors” and “adults”, and “singles” and “doubles” matches.
For quantitative statistical analysis, pooled means or mean differences with 95% confidence intervals (CI) will be calculated for movement variables reported by three or more studies. The quantile estimation method will be used to estimate the mean and standard deviations if median values are provided [7]. A random-effects meta-analysis will be performed with robust variance estimation to account for dependence of the study means [8,9]. The studies will be pooled using the inverse variance method [10]. Measures of means will be log-transformed for analysis and then back-transformed to ensure no implausible (i.e., negative) estimates are

obtained [11]. The standard error of the log-transformed mean will be calculated with the formula $\sqrt{(SD^2/(n*mean^2))}$ [12].

The measures of heterogeneity used will be Cochrane Q and the resulting chi-squared statistic, I^2 statistic, and 95% prediction intervals (PI). A 95% PI estimates where the actual effects are expected for 95% of similar studies that may be conducted in the future. The PI estimate is imprecise if the number of studies is low [13].

A correlation value of $\rho = 0.8$ will be assumed for all analyses if correlation values are missing. All calculations and graphics will be performed with the software R [14] and the extension packages 'metafor' [15] and 'robumeta' [9].

Qualitative Synthesis

The descriptive characteristics of each study will be summarised and presented in summary tables and text.

Subgroup analysis

The impact of the three main court surfaces used in tennis will be considered: hard court, grass court, and clay court.

Sensitivity Analysis

As correlation values will be unknown, a sensitivity analysis with a range of different correlation parameters will be performed ($\rho = 0, 0.2, 0.4, 0.6, 1.0$). Missing standard deviations will be imputed as the median value of the included standard deviations in the corresponding analysis [16]. Sensitivity analyses will be calculated without the studies with the imputed standard deviation.

DATA EXTRACTION

Two reviewers will independently extract the following data related to the characteristics of the included studies: name of the first author; the year of publication; country where the study was conducted; study design; population; sample size (participants and matches); age; sex (% male); playing level; court surface; sport class (Open or Quad); the assessment tool (s); comparison, and an overview of the outcome parameters of each study. Playing level will be determined by the level of tournament the players participate in, e.g., regional, national, or international, or by their ranking. Sport Class (Open or Quad) will be determined by the classification status described in the article. Court surface will be determined by the playing surface of the matches, i.e., hard court, clay court, or grass court. Differences will be resolved through discussion and a third reviewer is available if consensus can not be reached.

Contributions of each author:

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Author 9 - Linda J. Schoonmade
Author 10 - Rob Shaw
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