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COMPARISON OF PHYSICAL FITNESS BETWEEN PARALYMPIC TENNIS PLAYERS WITH AND WITHOUT SPINAL CORD INJURY

ORIGINAL ARTICLE

ABSTRACT

Purpose: : This study aimed to compare grip strength, upper limb explosive strength, sprint, and agility in the wheelchair between Paralympic tennis players with and without spinal cord injury.

Methods: This study was designed as a cross-sectional study. The participants were 18 Colombian wheelchair tennis players from the open category who were divided into two groups according to the condition that generated the disability: spinal cord injury (n=9) and without spinal cord injury (n=9). Sociodemographic and sports data were collected, as well as results of manual dynamometry, medicine ball throws simulating forehand, backhand and serve gestures, 5-, 10- and 20-meter sprint, T-Test and Spider test.

Results: According to our findings, tennis players who had a spinal cord injury obtained shorter distances in throwing the medicine ball by simulating the forehand (p=0.008), backhand (p=0.009) and serve gestures (p=0.012) and took longer to execute the 5- (p=0.050), 10-meter sprint (p=0.040), T-Test (p=0.037) and Spider test (p= 0.025) in comparison with those without spinal cord injury.

Conclusion: The results of the present study demonstrated that athletes who have a spinal cord injury throw the medicine ball shorter distances, are less fast and agile with the wheelchair compared to athletes who have other types of conditions. Therefore, it is essential that individualized interventions are generated by the interdisciplinary team, with emphasis on explosive strength and aspects of mobility in the wheelchair, considering the type of condition that generated the disability, as well as possible adjustments to the functional classification system.

Keywords: Muscle Strength, Para-Athletes, Spinal Cord Injuries, Tennis

OMURİLİK YARALANMASI OLAN VE OLMAYAN PARALİMPİK TENİSÇİLERİN FİZİKSEL UYGUNLUKLARININ KARŞILAŞTIRILMASI

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Bu çalışma, omurilik yaralanması olan ve olmayan Paralimpik tenis oyuncuları arasında tekerlekli sandalyede kavrama kuvveti, üst ekstremite patlayıcı kuvveti, sprint ve çevikliğin karşılaştırılmasını amaçladı.

Yöntem: Bu çalışma kesitsel bir çalışma olarak tasarlandı. Katılımcılar, açık kategoriden 18 Kolombiyalı tekerlekli sandalye tenisçisiydi ve sakatlığa neden olan duruma göre iki gruba ayrıldı: omurilik yaralanması (n=9) ve omurilik yaralanması olmayan (n=9). Sosyodemografik ve spor verilerinin yanı sıra manuel dinamometri, forehand, backhand ve servis hareketlerini simüle eden sağlık topu atışları, 5-, 10- ve 20 metre sprint, T-Testi ve Spider testi sonuçları toplandı.

Sonuçlar: Bulgularımıza göre, omurilik yaralanması geçiren tenisçiler, omurilik yaralanması geçirmeyenlere kıyasla, forehand (p=0,008), backhand (p=0,009) ve servis hareketlerini (p=0,012) simüle ederek tıp topu atmada daha kısa mesafe elde ettiler ve 5- (p=0,050), 10 metre sprint (p=0,040), T-Testi (p=0,037) ve Spider testi (p=0,025) gerçekleştirmeleri daha uzun sürdü.

Tartışma: Bu çalışmanın sonuçları, omurilik yaralanması olan sporcuların sağlık topunu daha kısa mesafelere fırlattıklarını, tekerlekli sandalyede diğer rahatsızlıklara sahip sporculara göre daha az hızlı ve çevik olduklarını göstermiştir. Bu nedenle, bireyselleştirilmiş müdahalelerin disiplinler arası bir ekip tarafından, patlayıcı kuvvet ve tekerlekli sandalyede hareketliliğin yönleri üzerinde durarak, engelliliği yaratan durumun türü ve fonksiyonel sınıflandırma sisteminde olası ayarlamalar göz önünde bulundurularak oluşturulması önemlidir.

Anahtar Kelimeler: Kas Kuvveti, Engelli Sporcular, Omurilik Yaralanmaları, Tenis.

INTRODUCTION

The evaluation of the Paralympic athlete is an issue that needs to be considered from different components: the first is the type of physical, visual or intellectual disability that the athlete has, the second corresponds to the sport and its characteristics, and the third is in relation to the eligible impairment that is linked to an underlying health condition among which is the spinal cord injury.

Following this order of ideas, a fundamental aspect in Paralympic sport is the functional classification, which seeks to group athletes with similar abilities to guarantee the fairest competition possible (1). Athletes who use a wheelchair have a great diversity of physical deficiencies and therefore there is a great variety of responses of physiological systems; coupled with the fact that the athlete and the wheelchair form a single unit where changes in either the subject or the chair will have an impact on overall sports performance (2).

According to the latest functional classification guidelines of the International Tennis Federation (ITF), wheelchair tennis (WT) has two sports categories: open (men's and women's) and Quad (mixed). Players are eligible to compete in the Open category if they have a permanent physical disability that compromises function in one or both lower extremities, while in the Quad category players are eligible if three limbs are compromised. This classification model, since it does not have a scoring system as in the case of other wheelchair sports such as basketball, handball, paddle tennis, among others, allows athletes with a wide variety of eligible physical deficiencies to compete in the open category.

In subjects with spinal cord injury, aerobic and anaerobic capacity and strength are inversely related to the level of injury and the integrity of the affected structures (3) among other aspects such as alterations in blood redistribution, the cardiac response and thermoregulation mechanisms (4–6). In contrast, the presence of physical deficiencies in the lower limbs, as is the case of people with lower limb amputation, presents a preserved trunk function that provides stability (7). On the other hand, athletes with injuries to the central nervous system such as cerebral palsy or stroke usually present increased muscle tone and an alteration in coordination that leads to imbalance and decreased muscle power (8).

In WT the movements are intermittent, multidirectional, and non-random, which challenges the player to change direction many times, with the need to accelerate between shots and decelerate before a shot. Although these aspects indicate that wheelchair mobility performance is a key performance factor (9), research is limited regarding the impact of the type of physical impairment that players have on their physical performance.

Some background information is the study by Sánchez-Pay and Sanz-Rivas (10) who evidenced in a sample consisted of 9 Spanish male high-level players, that WT players who had a spinal cord injury, in contrast to those who did not have a spinal cord injury, had lower values in all physical tests of strength, speed, agility and resistance. However, in that study a large number of statistically significant differences were not found, except in dynamometry of the dominant hand, 5-20-meters sprint, T-test and Hit and Turn resistance test. Previously Cavedon et al. (11) demonstrated that the severity of the impairment significantly affected the speed of the ball and the angle of the shoulder at the moment of impact of the ball, for which the authors suggested that the current classification overlooked the impact of disability on player performance, and therefore it was necessary to delve deeper into the topic and its future implications in the functional classification system.

In accordance with the previous approaches, it is necessary to recognize the specific needs of the sport in order to build solid foundations for the comprehensive approach to the athlete, considering that WT players with physical disabilities and with different eligible impairments criteria compete in the same category (Open). It was decided to carry out an investigation with the objective of comparing some aspects of physical fitness such as grip strength, explosive strength of upper limbs and mobility in the wheelchair between paralympic tennis players with and without spinal cord injury who compete in the open category.

METHODS

Study design and participants

This study was designed as a cross-sectional study. Totally 18 Colombian WT players selected to the I Paranational Pre-games 2023 tournament participated voluntarily. The study was conducted on December 7-10, 2022, at the District Racquet Park, Barranquilla, Colombia. Non-probabilistic convenience sampling was carried out, the sample consisted of 12 men (40.17 ± 11.13 years) and 6 women (25 ± 6.16 years), all classified in the open category. Participants were divided according to the type of condition that generated the disability into players with a spinal cord injury (SCI) (n=9) and players with other type of injuries (non-SCI) (n=9). The inclusion criteria were being duly registered for the tournament and having a minimum sporting experience of 6 months. Exclusion criteria included presenting an acute injury, general illness, or state of intoxication at the time of the evaluation. The sociodemographic and sports characteristics are presented in Table 1. All players agreed to participate voluntarily and signed the respective informed consent. This study was approved by the ethics committee of the Autonomous University of Manizales, Colombia (approval number: 143-141 of 11/09/2022) and was developed in compliance with the principles of the Declaration of Helsinki.

Instruments

Sociodemographic and sports data of the athletes were completed, such as age, sitting height, weight, sports experience, hours of weekly training and type of condition that generated the disability. Additionally, the results of 5 field tests were collected:

• **Dynamometry:** Dominant and non-dominant hand grip strength was measured with a Camry digital dynamometer (grip strength up to 200 lb/90 kg, 0.2 lb/100 g division). The test was carried out in the wheelchair sitting position with the arm extended and closed to the wheel, but without touching it (12).

• **Medicine ball throw:** The explosive strength of the upper limbs was evaluated through 3 tests of throwing a 2 kg medicine ball, simulating forehand, backhand and serve hits (12).

The participants stood behind the throwing line in a 45° position. A 10 m long measuring tape was placed on the court perpendicular to the throwing line and two evaluators marked the bounce zone of the recorded ball in 0.10 m sections:

a) Forehand/backhand: The ball was to be held with both hands on the throwing side (right or left), with the throwing hand providing the force, while the opposite hand was the guide. At the evaluator's signal, the player was to make an explosive movement and throw the ball with both hands as far as possible.

b) Service: The ball was to be held on the palm of the dominant hand to the side of the head. At the evaluator's signal, the player was to make an explosive movement and throw the ball simulating a shot put in athletics.

• **Sprint 20m:** Participants performed a 20-meter sprint holding the racket. To do this, the athlete was located 0.5 m from the starting line and, at the signal of the evaluator, completed the course in the shortest time possible. To record the total time for each section (0-5m, 0-10m, 0-20m), video recording was used with the MySprint app (MySp) (13). The methodology used by Ghigiarelli et al. (14) was adapted to guarantee the partial times of 0-5 m, 0-10 m, and 0-20 m by correcting the parallax of the video by placing 4 canes in adjusted positions (Figure 1).

• **T-Test:** A T-shaped circuit was marked out (Figure 2) which had to be completed as fast as possible. For this circuit, the player, seated in the wheelchair and holding the racket, was in the center of the court, behind the baseline, and at the signal of the evaluator he moved towards the intersections of the singles line with the service line, always passing through the central area of the court until returning to the starting area (12).

• **Spider Test:** The participant, sitting in the wheelchair and holding the racket, had to complete a circuit of maneuverability (Figure 3). The athlete was located behind the starting line, in front of the cone M located in the center of the baseline, and at the signal of the evaluator, the athlete went around the cone M, went to the right towards the cone A, went around it inside and went back again to go

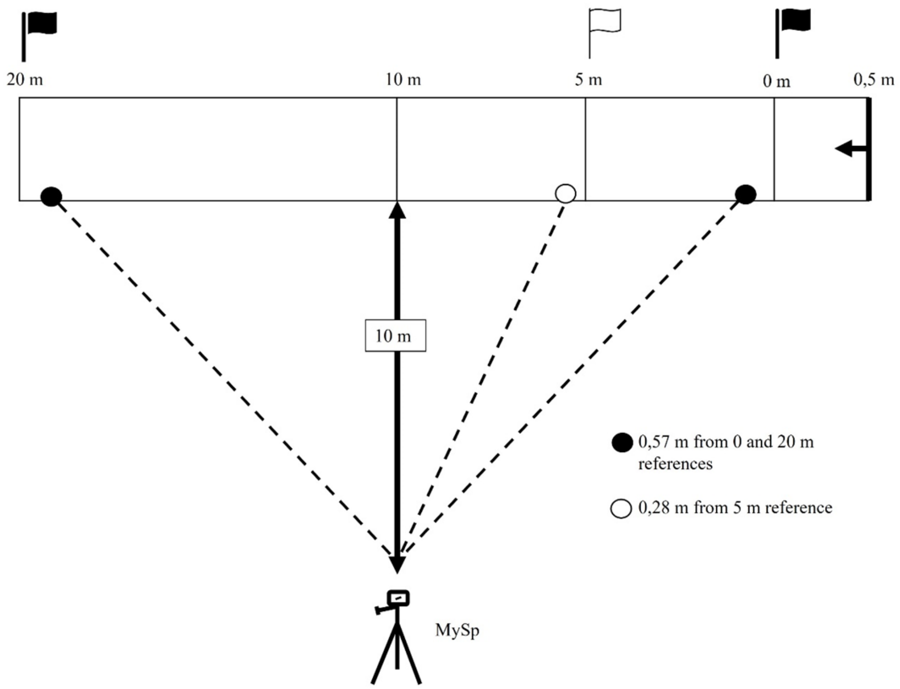

Figure 1. Reference scheme for placing poles in adjusted positions for recording the sprint with MySprint app.

around the cone M, then went to the cone B to go around it also inside and went again towards the cone M to go around it, this same route was done with cone C and D. The circuit was completed as fast as possible (15).

For each of the tests, three attempts were made with a rest time between each repetition of 2 min and the best value was recorded. For the wheelchair mobility tests, time was timed using the MySp.

Data collection was carried out in two sessions: the first was to complete the sociodemographic and sports characteristics questionnaire and the measurement of handgrip strength; and the second session for the remaining field tests. All tests

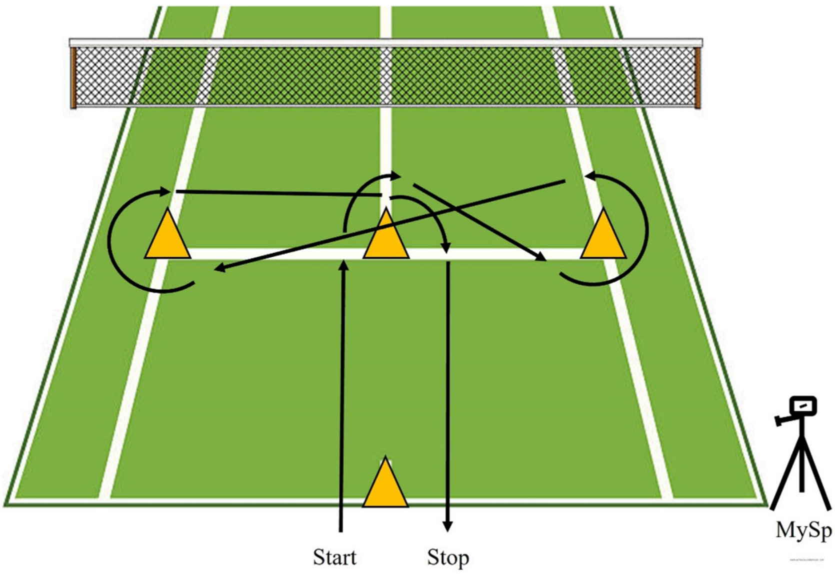

Figure 2. T-Test

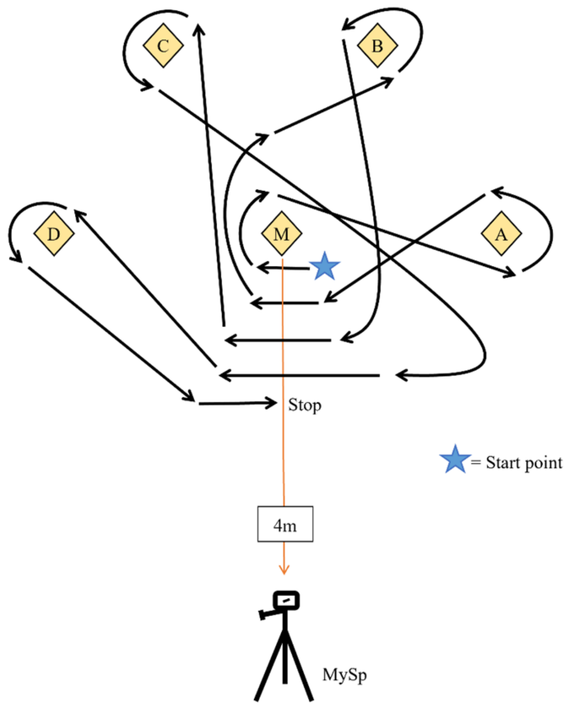

Figure 3. Spider Test (Distance AM = BM = CM = DM = AB = BC = CD = 1.2 m)

in the second session were performed outdoors on a hard surface tennis court with an ambient temperature between 28-30°C. Prior to the execution of the tests, the participants performed a 10-minute guided warm-up and carried out familiarization sessions with the purpose of reducing possible learning effects before recording the official marks for each test.

Statistical analysis

Data analysis was performed using IBM® SPSS® Statistics for Windows software (ver. 25.0; IBM Corp., NY, USA). A descriptive analysis was carried out presenting means ± standard deviation for the quantitative variables studied; and the sample was divided into two groups according to the type of condition that generated the disability. Due to the sample size, the Shapiro-Wilk and Levene tests were used to test the normality and homogeneity of variances for each variable. To make comparisons, the T test for independent samples and the Mann–Whitney U test were used for parametric and nonparametric variables, respectively. The $p < 0.05$ criterion was used for establishing statistical significance.

RESULTS

The sociodemographic and sports characteristics of the WT players are presented in Table 1.

According to the comparative analysis presented in Table 2, it was evident that players with non-SCI had better results in the dynamometry of the dominant hand (44.78 ± 8.83 vs 42.10 ± 12.38 kg) than players with SCI. But in the non-dominant hand SCI group was superior, however, none of these variables presented statistically significant differences. In terms of the explosive strength of the upper limbs, players with non-SCI threw the ball further in forehand (p= 0.008), backhand (p= 0.009) and serve throws (p= 0.012) compared to players with SCI, furthermore, in the sprint tests non-SCI group took less time to move at 5 m, 10 m and 20 m , with statistically significant differences in the distance from 0 to 5 m (1.79 ± 0.19 vs 2.13 ± 0.40 s, p =0.050) and from 0 to 10 m (3.26 ± 0.23 vs 3.86 ± 0.79 s, p=0.040). In relation to the agility tests, both in the T-test (p= 0.037) and in the Spider test (p= 0.025) the players with non-SCI took less time to execute compared to the SCI group, also with statistically significant differences.

Table 1. Sociodemographic and Sports Characteristics of the Study Participants

Variable	Sample (n=18)
Age (years)	35.11 ± 12.06
Sitting height (cm)	84.88 ± 4.75
Weight (Kg)	68.67 ± 19.42
Sports experience (years)	5.86 ± 5.01
Weekly training hours	11.83 ± 10.16
Type of Impairments (n (%))	
Spinal cord injury T3	1 (5.55)
Spinal cord injury T5-T6	3 (16.66)
Spinal cord injury T7-T8	1 (5.55)
Spinal cord injury T10-T12	1 (5.55)
Spinal cord injury T12-L1	2 (11.11)
Vertebral fracture T3-T6	1 (5.55)
Lower extremity poliomyelitis	2 (11.11)
Lower limb amputation	4 (22.22)
Polytrauma in lower limb	1 (5.55)
Lower extremity shortening	2 (11.11)

Data are expressed as mean ± standard deviation for continuous variables and ‘n’ were reported for categorical variables.

Table 2. Results of Physical Fitness Tests according to the Type of Condition that Generated the Disability.

Variable	SCI (n=9)	non-SCI (n=9)	p
Hand dynamometry			
Grip strength. Dom (Kg)	42.10 ± 12.38	44.78 ± 8.83	0.604
Grip strength. No Dom (kg)	41.62 ± 10.60	38.12 ± 9.77	0.477
Strength of upper limbs			
MBT forehand (cm)	3.78 ± 1.26	5.55 ± 1.23	0.008*
MBT backhand (cm)	3.52 ± 0.99	5.08 ±1.24	0.009*
MBT serve (cm)	4.41 ± 1.11	5.98 ± 1.25	0.012*
Sprint			
5 m (s)	2.13 ± 0.40	1.79 ± 0.19	0.050*
10 m (s)	3.86 ± 0.79	3.26 ± 0.23	0.040*
20 m (s)	7.02 ± 1.48	5.93 ± 0.44	0.077
Agility			
T-Test (s)	17.52 ± 2.76	15.18 ± 1.39	0.037*
Spider Test (s)	21.59 ± 2.70	19.04 ± 1.19	0.025*

Data are presented as mean± standard deviation. Dom: Dominant, No Dom: Non-dominant, MBT: medicine ball throw

DISCUSSION

The acknowledgement that tennis players with physical disabilities and with different eligibility criteria compete in the same category (open) has promoted research to build a functional classification system based on evidence as established by the International Paralympic Committee. In sports such as wheelchair basketball, studies have shown differences in general aspects of strength, aerobic and anaerobic capacity, agility, and speed in relation to the functional classification score (16,17) and type of deficiency that players present (18,19), as well as studies in handball (20,21) and sports dance (22) that highlight differences in wheelchair mobility according to functional classification.

Although there is no specific scoring system in the WT, the open category brings together a wide variety of athletes with different types of disabilities. In this case, the only report found in WT players is Sánchez-Pay and Sanz-Rivas (10) who identified statistically significant differences in the dynamometry of the dominant hand with higher values in players with non-SCI, as reported in wheelchair basketball players (18,23). Although there are few reports in Paralympic sports that measure the grip strength of the non-dominant hand, our study shows that players with SCI have a relatively similar grip strength in both hands compared to those who do not have a spinal cord injury. Probably because the first group are permanent wheelchair users and bilaterally activate their upper limbs to carry out their activities of daily living. However, during sports activities the grip of the non-dominant hand on the wheel rim is crucial for braking and turning, and above all for being a support point that the athlete uses to obtain stability and safely perform the technical gestures of tennis with the opposite side.

On the other hand, the results of this research indicate that tennis players with limb deficiencies caused by lower limb amputations at different levels or differences in limb length due to different musculoskeletal disorders, throw the medicine ball farther with differences greater than a meter distance compared to those with a SCI, like what has been reported in Spanish WT (10). In this regard, Goosey-Tolfrey and Leicht (4) mention that deficiencies depending on the level of spinal cord injury will determine the ability of muscle groups to contribute to physical performance, as well as possible asymmetries in remaining upper extremity or trunk function that reduce bilateral force production. It is also recognized that athletes with a SCI who present an alteration in the control and stabilization of the trunk will have a limitation in generating power in the kinematic chain (24), as evidenced by Cavedon et al. (11) in a sample of 31 Italian wheelchair tennis players, finding that ball speed and shoulder angle during serve were greater in athletes who had an injury that did not alter trunk function compared to those who had SCI at different levels.

WT is identified by its intermittent dynamics with intervals of moderate/high intensity and repetitive actions of short duration (25,26). From an overview, the game is characterized by being shorter and faster (27–29) compared to conventional tennis, which indicates that the mobility performance of the wheelchair in speed and agility are relevant to respond to the demands of the game. The results of the sprint tests with racket in hand in partial times of 5, 10 and 20 meters, T-Test and spider test, indicate that players with non-SCI are faster and more agile with the wheelchair with differences greater than 2 seconds compared to the other group, similar to the research of Sánchez-Pay and Sanz-Rivas (10) who also found superior performance in WT players with non-SCI.

In relation to these findings, the systematic review by Altmann et al. (30) highlights that the strength of the trunk muscles has implications in the positioning of the trunk when in a seated position and in the application of effective force on the wheel rims, which significantly impacts the propulsion of the wheelchair. Therefore, it is necessary to consider the degree of trunk functionality in the functional classification processes in the WT since notable differences are observed in the performance of different components of physical fitness between athletes competing in the same category.

A limitation of the study is the integrated analysis of male and female athletes, which indicates that the findings should be interpreted with caution, always respecting the individuality of each athlete through an evaluation and intervention adjusted to their functional possibilities. Likewise, another factor to consider is that the data were collected at the end of the sports season, so the test results may reflect lower physical performance in the entire sample, however, it was possible to evaluate most of the national sports talent under the same space-time and methodological conditions.

In conclusion, it is recognized that the type of condition that generates the eligible deficiency within the framework of the functional classification, in this case, tennis players with and without SCI, present significant differences in their physical performance; this invites the construction of individualized interventions by the interdisciplinary team, with emphasis on explosive strength and aspects of wheelchair mobility, considering the type of condition that generated the disability, as well as possible adjustments to the current functional classification system.

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Conflict of Interest: The authors report no conflict of interest.

Author Contribution: Concept: MAZP, OLHG and JRP; Design: MAZP and JRP; Supervision: OLHG and AAA; Resources and Financial Support: MAZP; Materials: JRP; Data Collection and/or Processing: MAZP, JRP and AAA; Analysis and/or Interpretation: MAZP and OLHG; Literature Research: MAZP and AAA; Writing Manuscript: MAZP and JRP; Critical Review: OLHG and AAA.

Explanations: None

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