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Developing reaction time measurement tool norms for table tennis athletes
Desarrollo de normas para herramientas de medición del tiempo de reacción para atletas de tenis de mesa

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Abstract. Table tennis coaches, athletes' selection teams, and researchers seek a rare yet essential tool: a precise measure of reaction time performance. In this 4D research and development (R&D), the researchers aimed to develop a table tennis athletes' reaction time (RT) measurement tool and norm the development process. Ninety participants (n=90), aged 17.97 years (99% CI: 17.7–18.2) with an average height of 168.05 cm (99% CI: 167–169), used the tool and the PLX DAQ Application recorded their data. Using RStudio and the descriptive statistics technique, we analysed the data: among key findings, the tool yielded proof of strong validity (Aiken V index = 0.92) and good reliability (ICC = 0.87). Athletes' categorization revealed four distinct RT range boundaries: 'Excellent' (3 athletes), 'Good' (6 athletes), 'Fair' (50 athletes), and 'Poor' (31 athletes), respectively with RTs limits of 12.1 and 13.1, 14.1 and 15.1, 16.1 and 17.1, and then 18.1 and 19.1 ms. Height significantly influenced RT (r = -0.46), while age did not. As height increased from around 167.5±175 cm, RT decreased below 15 ms. We recommend disseminating a tool that is valid, reliable, and susceptible to categorising athletes' performance.
Keywords: reactive agility, reaction time, 4D R&D, table tennis

Resumen. Los entrenadores de tenis de mesa, los equipos de selección de atletas y los investigadores buscan una herramienta rara pero esencial: una medida precisa del rendimiento del tiempo de reacción. En esta investigación y desarrollo (I+D) 4D, los investigadores se propusieron desarrollar una herramienta de medición del tiempo de reacción (RT) de los atletas de tenis de mesa y normalizar el proceso de desarrollo. Noventa participantes (n=90), de 17,97 años (IC 99%: 17,7–18,2) con una altura promedio de 168,05 cm (IC 99%: 167–169), utilizaron la herramienta y la aplicación PLX DAQ registró sus datos. Utilizando RStudio y la técnica de estadística descriptiva, analizamos los datos: entre los hallazgos clave, la herramienta arrojó pruebas de gran validez (índice V de Aiken = 0,92) y buena confiabilidad (ICC = 0,87). La categorización de los atletas reveló cuatro límites distintos de rango de RT: 'Excelente' (3 atletas), 'Bueno' (6 atletas), 'Regular' (50 atletas) y 'Malo' (31 atletas), respectivamente con límites de RT de 12,1 y 13,1, 14,1 y 15,1, 16,1 y 17,1, y luego 18,1 y 19,1 ms. La altura influyó significativamente en el RT (r = -0,46), mientras que la edad no. A medida que la altura aumentó desde alrededor de 167,5±175 cm, el RT disminuyó por debajo de 15 ms. Recomendamos difundir una herramienta que sea válida, confiable y susceptible de categorizar el desempeño de los deportistas.
Palabras clave: agilidad reactiva, tiempo de reacción, I+D 4D, tenis de mesa

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Introduction

Sports science and specific sports experts are always constantly carrying out research to find ways to measure athletes' specific skills accurately, (Faber et al,2021; Syahriadi et al., 2024; Koopmann et al., 2020). However, accuracy often is lost due to inconsistencies either of the controversial skills measured, the tool used, or the stages through which the measurement occurred, (McNeil, Spittle, and Mesagno, 2021). That is why interdisciplinary studies are nowadays gaining momentum as they mobilize experts in different domains to solve multi-polar problems, (Müller and Kaltenbrunner, 2019; Woods et al, 2021; Mandan et al., 2024; Latief et al., 2024).

Developing a non-planned movement measurement tool for net game athletes' skills is an illustration of cases requiring multi-discipline expertise, (Buekers et al., 2017; Lozano, Ávalos-Ramos, and Vega-Ramírez, 2020). An expert of table tennis, for instance, aiming to develop a tool that measures table tennis athletes' reactive agility would require expertise in that field, that of net games sports measurement, and sports engineering, briefly interdisciplinarity, (Browne, Sweeting, Woods, and Robertson, 2021).

To develop a sport-specific athlete skill measurement tool, there are a series of stages for the findings to be accepted in the research community (Tan et al., 2023). To begin with, researchers adhere to research and development theory. For practicality, we will illustrate the normative steps into the research and development (R&D) of a reaction time measurement tool for Table Tennis Athletes so that the resulting impact can improve athletes' performance more accurately, in-depth, and optimally.

As with any study, R&D should have clear needs it intends to cater to or gaps it fills, which explains why researchers are expected to do needs analysis, (Dwivedi et al., 2024; Widyastuti et al., 2024; Liza et al., 2024; Claudino et al, 2019). This early stage of net game athletes' skills measurement tool consists of three sub-steps:

1. identifying Standards in the Sports Field: what should be done when measuring athletes' reaction time
2. identifying actual status or the actual practices in measuring table tennis players' reaction time
3. making a comparison between actual practices in measuring reaction time in this field with the existing theoretical standards or what should be done.

Table tennis is one of the sports disciplines whereby athletes exhibit high speed associated with both cognitive (e.g. reaction time) and physical (e.g. footwork) actions, (Castellar, 2019; Guo, Liang, Xiao & Hao, 2020). Reaction time refers to the duration an athlete takes to respond to a stimulus during a game, (Kumar et al., 2020; Such stimuli can be, but are not limited to, the opponent's shot like 'serve' or 'return', the ball trajectory, etc. Reaction time is a dimension that includes other components such as perception, processing, and motor execution. This means there is a duration that spans between a table tennis player recognizing the stimulus, processing it mentally, and physically executing a related response.

In normal conditions, any new sport-specific measurement tool should not be developed before identifying the challenges it comes to solve, (Gopinathan, 2022; Pocari, Bryant, Comana, 2015). Needs are identified by comparing standards with actual status, (Kelly, 2019). This sheds light on existing problems or discrepancies, which are the real problems that need to be solved by experts. Next comes the choice of a tool development design. This is a serious struggle in the sports science community because there are few resources about R&D stages specific to sports disciplines. Experts who want to develop domain-specific tools modify existing development designs like Borg and Gall's, 4D, etc. But there are a million reasons to doubt findings resulting from these raw design adaptations.

It is crucial to define what reactive agility is before developing a tool that measures its sub-component of reaction time. Reactive agility refers to reactive agility in table tennis encompasses swift adaptations to unpredictable situations, allowing players to react effectively during intense rallies, (Munivrana, Jelaska, and Tomljanović, 2022).

There should be a reactive agility measurement tool as well as a pre-planned agility measurement tool. Tests that measure the reactions of net players that have been previously planned. Such as the previous agility test measurement tool by Sekulic et al. (2017), the Rago et al. dart agility test (2020), Dewangga, Yudhistira, Tomoliyus agility test (2010) in the Kumite karate category, ladder agility test (Smits-Engelsman et al. (2019),), ladder agility test (Smits-Engelsman et al. (2019),), Illinois agility test (Smits-Engelsman et al. (2019),), Illinois agility test 2019), Illinois agility test (Usma-alvarez C. et al., 2014), or the agility test constructed by Danardono et al. (2022). However, there is a comparison between the previous measurement tool and the new measurement tool can be seen from the construction, aspects of distance, accuracy, speed, ergonomics of use, and additional features of using technology, which can increase the usefulness of technology to the education and training process (Ramos-Álvarez et al., 2024).

The research in scientific research databases for table tennis reactive agility test is quasi-inexistent. There are not even formal, or data evidenced standards cutoff scores for reaction time; rare is also the development of tools for sports-specific discipline. There might be many reasons for this lack of tool but two are worth raising: the big challenge posed by measuring reactive agility for net games since players are influenced by both internal and external factors, (Nóbrega, et al., 2023). The other reason might be that such tool development requires multi-disciplinary expertise.

However, the challenging nature of measuring reactive agility skills and related components should not hamper discipline experts from exploring options, (McNeil, Spittle, & Mesagno, 2021). The current research trends determine the related practices in force among the table tennis academia. As we are concerned with developing a table tennis reactive agility measurement tool, especially for athletes' reaction time, it is better to explore what has already been done to later establish needs.

Reaction time held the attention of table tennis researchers. Reaction time refers to the duration it takes for an individual to respond to a stimulus, (Janicijevic & Garcia-Ramos, 2022). In the context of table tennis, this stimulus typically arises from the opponent's actions, such as serving the ball or executing a shot. It encompasses the time interval between the presentation of the stimulus (e.g., the ball's trajectory) and the player's subsequent response, e.g., returning the shot, (Pojskic et al., 2022). One may say that reaction time spans from a stimulus and ends when a motor response is onset, (Castellar, Pradas, Carrasco, La Torre, and González-Jurado; 2019; Horníková, 2022).

The aspect of reactive agility biomechanics is also covered (Wong, Lee & Lam, 2020; Li, 2022), so is the proportion of footwork versus other skills entering into play during a table tennis game (Faber, Koopmann, Büsch, Schorer, (2021), specific table tennis athletes' body parts function, an illustrative case being the exploration of how ankle proprioceptive functions during rallies, (Shi et al., 2023) or the lower limb related insights in (Shao et al., 2020). Some authors also explored ways to optimize reaction time and footwork for table tennis players, (Badau and Badau, 2022) or factors determining the table tennis athletes' reactive agility performance, (Horníková, 2022).

Given the limited number of reactive agility measurement tools in the existing literature, current research trends and methodologies involve technology for the practical application of measurement tools. Due to the nature of reactive agility measurement tools, they must be responsive to unexpected movements within a few milliseconds. Particularly in response capture for net play, there is an urgent need to develop a complex reactive agility measurement tool that measures athletes' reaction time and footwork aspects. Therefore, this research aims to illustrate the steps of developing a reactive agility tool through the development of a natural table tennis athlete's reaction time and footwork measurement tool, then systematically analyze the existing literature on table tennis athlete's reaction time and identify the different categories, then create a table tennis athlete's reaction time measurement tool that coaches, athletes, and researchers can access.

Thus, the research questions included the following:

1) How to develop a valid and reliable table tennis athletes' reaction time measurement tool?

2) What qualities should the developed table tennis reaction time measurement tool satisfy to be ready for use?

Materials and Methods

Participants

The participants' characteristics in this R&D reaction time tool are:

- Age: 17.97 ± 0.223 meaning that, with a 99% Confidence Interval and standard error margin of SE=0.223, the subjects' age mean lies between 17.7 and 18.2 years
- Height: 168.05 ± 0.885, that is, with a 99% Confidence Interval and standard error margin of SE=0.885, the subjects' height mean lies between 167 and 169 cm

Six experts did appraisals and validation of the tool design, components, and procedural guide. The whole sample used was 90 table tennis athletes.

Measurements

Through this research and development, the researchers developed a tool that can be used to measure the reaction time of table tennis athletes. The unit of measurement for reaction time is usually milliseconds (ms). The PLX DAQ application records data well in terms of the duration of each athlete's reaction to stimuli. The PLX DAQ app provides easy Excel spreadsheet analysis of data collected in the field, laboratory analysis of sensors, and real-time monitoring of equipment.

Research Design

This is a research and development (R&D), with 4D design, that is, define, design, develop, and disseminate. Since this is normative research that embeds illustration as a case study, it is crucial to elaborate a bit on each of the four stages, (Alim & Yuliarto, 2022; Wibowo, Dese & Nopiyanto, 2024).

Define

During the Define stage, the researchers reviewed the existing literature on the concept of reactive time, which led to the conceptual definition of 'reactive agility'. It refers to the rapid movement of an athlete's whole body with a change in directional speed after he/she receives a stimulus stimulus (Sheppard & Young, 2006; Nugroho et al., 2022). Such rapid movements are related to other cognitive and physical qualities of athletes, such as reaction time, which can be trained (Horníková, 2022; McNeil, Spittle, and Mesagno, 2021; Sinkovic, Novak, Foretic, Kim and Subramanian, 2023).

The needs analysis consisted of determining standards, actual status, and front-end analysis of discrepancies existing in measuring table tennis athletes' reactive agility, especially the reaction time and footwork components. Categorizing athletes' reactive agility on the two components was also part of the needs analysis, as illustrated in table 1. below:

Table 1.
Theoretical Table Tennis Athletes' Reaction Time Categorisation

Category	Indicators
Excellent	Lightning-fast Reaction Time: Reacts swiftly to opponents' shots
Good	Above-Average Reaction Time: Reacts reasonably quickly
Fair	Average Reaction Time: Reacts adequately
Poor	Slower Reaction Time: Reacts slowly

Given the existing literature, table tennis athletes' reaction time can be categorized as excellent, good, fair, and poor. The athletes in the excellent category take a relatively short time (in milliseconds) to respond to opponent-based stimuli. Equally, the athletes with the longest reaction time are labelled as having "poor" reaction time. It takes them the longest time to react to their opponent-rooted stimuli, which is very disadvantageous.

Design

At the Design stage, the researcher designs the initial construction design according to the literature review on the concept of reaction time. Furthermore, the selection and review of appropriate media for an application that is suitable for the initial construction design, including a description of the agility measurement tool. So that the design stage produces an achievement:

- the prototype;
- the tool's physical components;
- the series of electronic units;
- the flowchart software

Develop

At this stage, the behaviourally stated objectives were converted into an outline first, and then a detailed reaction time measurement early tool was made. This was followed by a set of expert appraisals, whereby sports sciences, sports engineering, and table tennis agility measurement expressed their technical points of view on the early tool design and procedures. Based on their feedback, the tool was revised, and further refinement was achieved. After expert appraisals, the researchers did initial trials on real users, that is, meaning that table tennis athletes iteratively used the tool, related revisions were made, and then it was retested until the reactive agility measurement tool worked consistently and effectively. This was proven by related test-retest reliability whereby related data were recorded simultaneously during trials using the PLX DAQ Application.

Disseminate

After trials and consistency in measuring table tennis athletes' reaction time were achieved, a summative evaluation of the tool was done. Such an evaluation included, under replicable conditions, adequacy and relevance re-examination. To substantiate qualitatively and quantitatively such an evaluation, one of the replicable conditions chosen was to use the tool to measure 90 athletes' reactive time. The usage guide was compiled, the tool was packaged appropriately, and dissemination sessions were held in table tennis trainers and athletes' communities.

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Statistical Analysis

RStudio-2023.12.1-402 was used to analyse the data collected. The quantitative measures considered include descriptive statistics namely the means ($\bar{x}$), standard deviation (SD), minimum score (MIN), maximum score (MAX), category boundaries, One-way ANOVA, and scatter plot. The researchers computed the validity index by calculating the Aiken V index and they estimated the tool reliability index using interclass correlation (ICC).

Results

Quantitative Data

Developed Tool validity and reliability

Two important metrics were considered concerning the developed reaction time measurement tool: its validity and reliability. The following records were collected for each of those metrics. The tool's overall validity was computed using the Aiken V index for five components examined by involved discipline experts, that is, sports engineers and table tennis athletes' performance measurement lecturers, for the appraisals of the tool. The components appraised by those experts included:

- Concept Definition
- Prototype Design
- Unit Input Circuit (UIC) or Unit 1-5
- Equipment components suitability
- Operational Flowchart

The resulting overall Aiken value was computed in Rstudio, the two last line codes being:

```
> v <- aiken_v_df(data[, -1])
> v
[1] 0.9166667 1.0000000 1.0000000 0.9166667 0.9166667 0.9166667 0.8333333
cat("Average Aiken V index:", round(average_aiken_v, 3), "\n")
Average Aiken V index: 0.929
```

So, the overall Aiken V index obtained was V=0.92

As far as the reliability of the developed tool is concerned, for the sake of precision, data collected through the PLX DAQ Application were computed in RStudio and the last line of the R code was:

```
> ICC(TestRet,missing=TRUE,alpha=.05,lmer=TRUE,check.keys=FALSE)
Single_random_raters ICC2 0.87
```

The ICC coefficient is 0.87, which shows how consistently the tool would yield similar results if replicated in similar conditions

The developed tool assemblage can be seen in Figure 1 below:

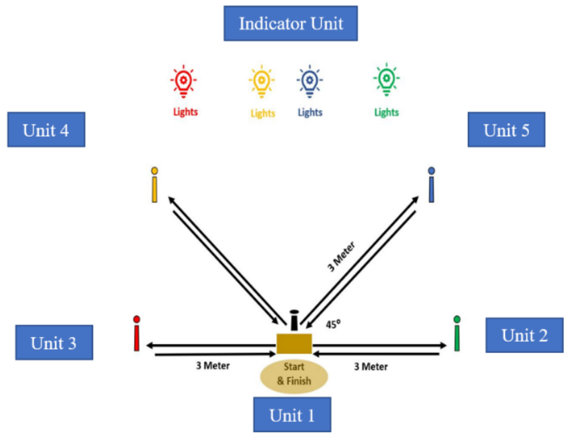

Figure 1. Early Sensor-Based Reactive Agility Measurement Tool

Descriptive Statistics

Reaction Time

To subdue the tool to repetitive or iterative conditions, it was used to measure table tennis athletes' reaction time (RT). The results are recapped in Table 1 below:

Table 2.
The Reaction Time Component

Measure	Mean	SD	Min	Max
	16.47	1.30	12.14	18.67

Table 1 summarizes data for the athletes' reaction time. The RT mean is 16.47 ms, which means that with a related slight standard error of measurement, it should lie between 16.47 ± 0.337, that is, between 16.1 to 16.8 ms. The athlete with the best reaction time (Min) score has an RT=12.14, while it took the least performing a duration of 18.67 ms to react to the stimulus.

Categorizing Athletes' Reaction Time

The tool does not include an automatic athletes' RT categorization. The researchers did it using RStudio, an open-source software, and the grouping criteria were computed in R Studio as follows:

```
# Define category boundaries
frq(data, auto.grp = 4)
# total N=90 valid N=90 mean=16.48 sd=1.30
```

Table 3.
RT Category Boundaries

RT Ranges in ms	Category
12.1-13.1	Excellent
14.1-15.1	Good
16.1-17.1	Fair
18.1-19.1	Poor

To be able to categorize the table tennis athletes' RT performance, the range boundaries were calculated first. Given the RT mean and standard deviation, the frq(data, auto.grp = n) function was used while n, the number of categories, was set to 4. The resultant categories include RT in ms and they are in ascending order: from the shortest to the longest reaction time; the smaller an athlete's RT, the better that athlete is at reacting to opponents' ball return, shots, etc.

Using the different RT ranges for each category boundary, it was easy to group athletes according to their performance. The following R functions or codes were used:

> # Create custom labels for the categories

> data$RT_Category <- cut(RT, breaks = c(12.1, 13.1, 15.1, 17.1, 19.1),

+ labels = category_labels, include.lowest = TRUE)

> # Create a summary table with counts for each category

> summary_table <- table(data$RT_Category)

> # Display the summary table

> summary_table

Table 4.
Athletes' RT Performance Grouping

Categorizing Table Tennis Athletes' RT			
Excellent	Good	Fair	Poor
3	6	50	31

As Table 4 shows, there are four categories: excellent, good, fair, and poor. Given the athletes' RT performance, 3 athletes were classified as having excellent RT (comprised between 12.1 and 13.1ms), then 6 were found to have good RT as their records range between 14.1 and 15.1 ms. The fair category amassed most athletes as 50 out 90, that is, 55.5%, with RT within the 16.1-17.1 ms boundary. The category labelled as "poor" has 31 (34.4%) members, which means that athletes take the longest time in reacting to opponents' related stimuli: their RT are between 18.1 and 19.1 ms

The results of the scatter plot test to see the relationship between the variable reaction team (RT) versus height can be seen in Figure 2 below:

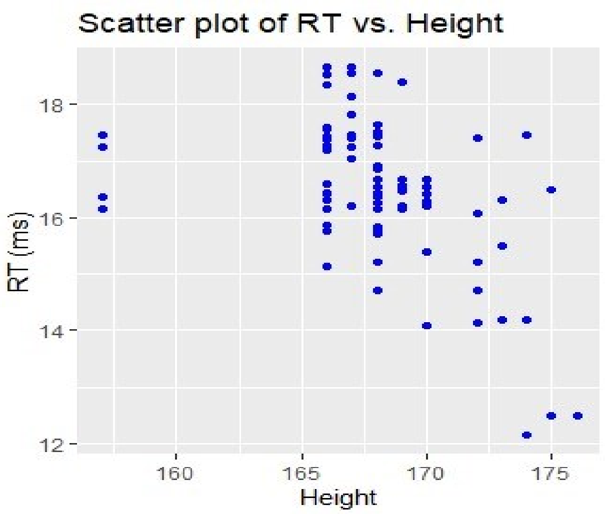

Figure 2. scatter plot of reaction time versus height

Scatter plot results of reaction time (RT) versus height are shown in Figure 2. The minimum height is 157, and the maximum height is 176, stating that the scatter plot test results clearly show that reaction time (RT) is related to height. It can be observed that at a height of 165 cm, the RT time ranges between 15 and >18 ms, while at the height limits of 167.5 and 175 cm, the variability is more excellent, resulting in shorter RT times, including RT times < 15 ms. Thus, RT tends to

Table 5.
Athletes'' Height Component

Measure	Mean	SD	Min	Max
	168.05	3.42	157	176

With the 99% Confidence Interval, given a mean of 168.05 and SD=3.42, a standard error of measurement becomes 0.885, reassuring that the athletes' height means estimate lies between 168.05 ± 0.885, which means that the average lies between 167 to 169 cm.

Equally, the same reasoning is applied to the athletes' age component as related descriptive statistics indicate the following values:

> Age

Table 6.
Athletes' Age

Measure	Mean	SD	Min	Max
	17.97	0.86	17	19

Table 4 shows that with a computed mean of 17.97, researchers were 99% confident that the age means for the athletes is between 17.97 ± 0.223: the age mean fell within 17.7 and 18.2.

Since the Scatter Plot is just a visual that can be subjectively explained qualitatively, it is better to analyse the existing interaction between athletes' RT, Age, and Height.

Table 7.
Pearson Correlation

		RT	Age	Height
RT	Pearson Correlation	1	.106	-.464**
	Sig. (2-tailed)		.319	.000
	N	90	90	90

Table 7 shows that there is no significant relationship between Age and RT for the sample on which the RT measurement tool was used. However, the ** indicates that r = -0.464 for RT*Height.

For further proof, we performed a simple linear regression to examine whether Age and Height significantly predict Reaction Time (RT). The fitted regression model was:

RT = 44.33142 + 0.07942 * Age - 0.17425 * Height + E

Table 8.
Linear Regression

Variable	Coefficient (β)	p-value	Interpretation
Intercept	44.33142	< 0.0001	RT when Age and Height are zero
Age	0.07942	0.584	No significant effect on RT
Height	-0.17425	< 0.0001	Increase in Height → Decrease in RT (Tall athletes have the shortest reaction time)

Based on the correlation and regression results, the meaning of Table 8 lies in the interpretation column. There is no significant effect between Age and RT, while Height and RT tend to have a negative relationship with a Pearson correlation of -0.464. So, as stated in Figure 2. scatter plot of reaction time versus height, there is a moderate relationship between Height and RT: for the sample used, the taller a table tennis athlete is, the shorter his RT is; a small RT means that it takes the shortest time for the athlete to react to stimuli from an opponent.

ANOVA Results

For further query for the proof of interaction between Age, Height, and RT, we performed a one-way ANOVA to assess whether there is a statistically significant difference in Reaction Time (RT) based on the combined effects of Age and Height.

Table 9.
One-Way Anova

Variable	df	Sum Sq	Mean Sq	F value	Pr(>F)
Age	1	1.71	1.71	1.257	0.265
Height	1	31.28	31.28	22.998	< 0.0001

For the Age variable, the p-value is 0.265 (>0.05): this indicates that for the sample under study, Age does not significantly contribute to explaining RT.

However, given the p-value < 0.0001 for Height, there is an indication that Height has a significant effect on RT. Indeed, the linear regression equation shows that Hight can explain RT at a rate of 17.4%, which is not bigger, but not insignificant either.

Discussion

This R&D, any research and development, includes two products: the idea of norming or guiding table tennis equipment or physical (not a test) tool development and then a real study whereby the developed tool was used to collect 90 athletes' RT values, the discussion is going to cover these two aspects.

Answering the research question about how to develop a table tennis reaction time measurement tool, normatively speaking, based on the 4D R&D design (any table tennis discipline-related measurement tool development should ascribe under the design stage, the definition of the concept for which a tool is going to be developed, then the standards around it and its actual status about the concept. With this information, needs or gaps to be filled through developing that concept-related tool can be sensed based on the discrepancies between the standards and actual status. Under this stage, the tool development objectives are also formulated. All these development stages, procedures, and conditions observed would be norms to be followed by any table tennis measurement tool developers or researchers, which answers partly research question one.

Next, the reliability and validity coefficient indices are necessary to complete the answer to the research question about the developed tool quality metrics. For the tool components' content validity, the Aiken value index obtained was a V=0.92. This means that the experts who appraised it found its components reliable and adequate. This echoes the high content validity reported by (Nugroho et al., 2022; Susiono et al., 2024). The excellent tool validity highly depends on its adequacy. The more the experts found that the components represent the concept holistically, they tend to appraise it very favourably, (Qowiyyuridho and Tomoliyus, 2021).

For the tool reliability index, the intraclass coefficient of ICC = 0.87 was obtained; it is in the very high or good category, (Retnawati, 2016; Koo & Li, 2016). It surpasses indeed the Munivrana, Jelaska, and Tomljanović, (2022) reactive agility test between-subject reliability Alpha=0.76. It is even far better than the inter-rater reliability of Rxx = 0.500 in Nugroho, Tomoliyus., Alim, and Fauzi (2022). It is rather close to the ICC=0.92 observed in Padulo, Pizzolato, Rodrigues, Attene, Curcio, and Zagatto (2016). With these similarities and differences, the tool reliability index value is very high, indicating that consistency in yielding similar results, if replicated in similar conditions, is undeniable.

One of the useful qualities of measurement tool is its ability to categorize athletes' performance on a given variable. There are not many cutoff scores to compare to when it comes to categorizing table tennis players' reaction time. The existing table tennis discipline literature does not yield much of studies that tested or developed tools specifically to measure athletes' reaction time. However, results in this R&D study indicate that the athlete with the best reaction time (min.) score has an RT=12.14 ms, while it took the least performing a duration of 18.67 ms to react to the stimulus.

Since the tool does not have an automatic athletes' RT ranking component, the athletes' RT performance ranking was done based on the classification made during the "Define" Stage. Such athletes' RT categorization echoes Hahsler, Buchta, Gruen, and Hornik (2021) the frq(data, auto.grp = n) function that splits data into n categories based on the RT mean and SD; which is similar to Ludecke (2018) categorization and supported by Castellar, Pradas, Carrasco, La Torre, and González-Jurado (2019) views on athletes' RT ranking.

As far as categorizing athletes according to their RT, only 3 athletes are classified as having 'excellent' RT (comprised between 12.1 and 13.1ms), then 6 have 'good' RT as their records range between 14.1 and 15.1 ms. The 'fair category' amassed most athletes as 50 out 90, that is, 55.5%, have RTs that fall within the 16.1-17.1 ms boundary. The category labelled as 'poor' has 31 out of 90 (34.4%) members, which means that athletes in this category took the longest time in reacting to opponents' related stimuli: their RT are between 18.1 and 19.1 ms. This finding aligns with the existing literature as it especially resonates with Zhu, Pi, Zhang, and Gu (2022) who differentiate professional from non-professional table tennis athletes. This finding resonates with the conclusion that tennis players react to opponent-based stimuli faster than those who do not play such a game, (Bhabhor, Vidja, Bhanderi, Dodhia, Kathrotia, and Joshi, 2013), while it is opposite to the shorter reaction time of 'men' reported in Lee et al. (2021).

Another aspect worth commenting on is the effect of height and age on athletes' reaction time. There is a linear relationship (r=-0.46), which highlights a moderate (Horníková, 2022) relation between height and reaction time for the sample of athletes studied. As height increases from around 167.5±175 cm, RT tends to decrease below 15ms. Indeed, the linear regression equation shows that height can explain RT at a rate of 17.4%, which is not insignificant. What is more, there is no significant relationship between Age and RT for the sample studied, a finding similar to Hornigova, Doležajová, Sedlacek, Šagát, and Balint, (2017). This also adds to the list of other athlete's characteristics that do not react or have an effect on their reaction time like the Body Mass Index (BMI) as concluded in Jiménez-García, Martínez-Amat, Hita-Contreras, Fábrega-Cuadros, Álvarez-Salvago & Aibar-Almazán (2021).

At the Dissemination stage, the overall results include these tool characteristics:

- its components had to be adequate or valid: the validity index of Aiken V=0.92 proves how valid the experts who appraised it found it;
- its reliability or consistency: the ICC=0.87 showcases that it has a high or good reliability index, which means that if replicated in the same conditions, results would be consistent or similar to those obtained in this R&D.
- ability to categorize the athletes' performance: based on the theoretical categorization of table tennis players' RT categorization, the materialization of such categorization was computed separately to ensure this quality was met. The use of Hahsler, Buchta, Gruen, and Hornik (2021) the frq(data, auto.grp = n) function helped ensure this materialisation as it splits data into n categories based on the RT mean and SD. With slight additional calculations, though not automatically done with the tool, it became easy to get athletes categorized as having Excellent, Good, Fair, and Poor RTs.

So, before disseminating to table tennis communities (coaches, students, or researchers), we made sure that the developed tool satisfied or met those qualities, which answers research question two. Upon its summative-related evaluation, it had to satisfy first the criteria or qualities of being valid, reliable, and susceptible to categorize athletes' reaction time. These qualities are considered when coaching, selecting athletes, researching, and training in the table tennis discipline.

This present reaction time tool measurement was developed following verbatim the 4D development design steps outlined above. From the Experts' appraisals, the content validity of the tool was estimated, after the related revisions, the tool was tried out and the reliability index was computed. Practically, in our study, the replicable conditions were created by measuring 90 table tennis athletes' reaction time in games and matches. This allowed for the re-examination of the tool's relevance and suitability. The end product satisfied or met the qualities of being valid, reliable, and susceptible to split table tennis athletes' reaction time into categories. So, normatively speaking, as a pioneer study in real table tennis physical (not a test) measurement tool, this R&D practically normed development stages and quality metrics for researchers and tool developers who would embark on following our footprints.

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