Chapter

The Use of Exergames in Motor Education Processes for School-Aged Children: A Systematic Review and Epistemic Diagnosis

Dirceu Ribeiro Nogueira da Gama, Andressa Oliveira Barros dos Santos, João Gabriel Miranda de Oliveira, Juliana Brandão Pinto de Castro and Rodrigo Gomes de Souza Vale

Abstract

This study aimed to diagnose the current state of knowledge about the use of exergames in the motor education processes of school-aged children. We conducted a systematic review following the PRISMA recommendations. Web of Science, MedLine (via PubMed), ScienceDirect, and Scopus databases were searched in December 2020 with the terms "exergames", "motor education", and "children". We used the Jadad scale and the Systematization for Research Approaches in Sports Sciences instrument to evaluate the surveyed material. Seventeen articles met the inclusion criteria. We observed that: 1) the use of exergames by children can increase the motor skills of locomotion and control of objects, in addition to the levels of physical fitness, but the magnitude and duration of these increments remain inconclusive; 2) the articles exhibited theoretical and methodological weaknesses; 3) empirical-experimental investigations centered on intervention studies are hegemonic; 4) the theories of Sports Training, Didactics, and Human Movement underlie the studies, referring to an interdisciplinary crossing between Sport Psychology, Sport Pedagogy, Sport and Performance, and Sport and Health; 4) researches with alternative designs are necessary; 5) we recommend to approach this issue according to other perspectives, such as Biomechanics applied to Sport, Sports Medicine, Sociology of Sport, and Philosophy of Sport.

Keywords: child, motor skills, video games, schools, physical education

1. Introduction

The development of fundamental motor skills is an essential prerequisite for the competent performance of several types of physical activities [1]. Evidence shows

that the triggering of this process in a systematic way since childhood affects both the practice of efficient sports performances in youth and the adoption of active lifestyles in adulthood [2–4].

In theoretical terms, fundamental motor skills can be subdivided into two broad classifying categories: locomotion skills and object control skills [5]. Locomotion skills include running, jumping, marching, climbing, riding, swimming, skating, among others, while object control skills refer to transporting, intercepting, wielding, designing, and controlling implements in actions related to receptions, throws, bouncing, conduction with feet and hitting [6]. The development of physical fitness regarding balance, coordination, agility, speed, and reaction time contributes positively to the increase of these two types of skills, as they enable the body to perform them properly [7, 8].

Overall, the first manifestations of fundamental motor skills occur after the child stabilizes the bipedal posture and starts to walk alone. Participation in games is relevant to, even at random, have the opportunity to perform body skills in the challenges inherent to these activities. The continued exposure to such stimuli contributes, over time, to acquire increasing levels of motor proficiency [9, 10].

On the other hand, any obstructions in the course of motor evolution even in the first years of life can cause delays with an extension until puberty if they are not properly reversed in a timely manner. If they remain unchanged for long periods, deficits in locomotion and object control skills affect the behavioral and psychic domains. This can decrease the interest in the practice of physical activities, perturb self-esteem, and cause distortions in body image [11].

School Physical Education programs represent a strategic possibility of facing this scenario if they are given diligently with regard to content planning and execution. Likewise, the provision of public leisure policies focused on combating sedentary lifestyles among young people should be seen as measures of equal significance [12, 13]. Although such actions are essential, public health indicators attest that, by themselves, they are limited to promote the increase of basic motor skills of infants and adolescents related to the actions of running, jumping, swimming, throwing, launching, among others, according to minimally reasonable standards of technical effectiveness [14, 15]. In a 13-year longitudinal study, Hardy et al. [16] investigated the development levels of fundamental motor skills in children and adolescents. In the end, they observed that less than 50% exhibited basic motor skills at satisfactory levels. Similarly, Brian et al. [17] found in a recent study carried out in the United States of America (USA) that approximately 77% of the analyzed sample of infants and pubescents were in a situation of delayed motor development [17].

The cogency of this context and the urgency to face it has led academics and professionals in the area of human motricity to research and propose original solutions during the last two decades. One of them refers to the use of active video games (exergames) in children's motor education processes [18–20]. Supporters of this idea state that exergames can be helpful tools for teaching, acquiring, and improving the motor skills of children and adolescents of different ages, sex, biological maturity, and clinical conditions. The undeniable popularity of these types of games among young people, mainly as a residential entertainment option, is the main justification to support such a suggestion. Conceptually, exergames are digital games that require movement of the body as a whole, through devices that convert the individual's real movements to the virtual environment. This allows them to practice simulated sports, fitness exercises, and/or other playful and interactive physical activities. Unlike conventional video games, exergames require physical effort [18–20].

The innovative character of this approach not only ratifies the creativity of its proponents but also demonstrates the commitment to try to equate and solve the

problem at hand. However, as it is a recent issue, it is legitimate to raise the hypothesis that studies related to the theme are still in an early stage. Thus, identifying the characteristics of the exergames as to the criteria for demarcating objects, data treatment techniques, sample compositions, and the applicability of the results is a necessary task both to have a broader view of their theoretical-methodological profiles and for the emission of epistemic diagnoses/prognoses. Therefore, the objective of this study was twofold: 1) to identify, through a systematic review, the ways of using exergames in the processes of motor education of school-age children; 2) to diagnose the epistemic state of this use in the context of Sport Sciences.

2. Method

This systematic review was drafted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations [21].

2.1 Search strategy

A search was made without time or language filters in December 2020 in the Web of Science, MedLine (via PubMed), ScienceDirect, and Scopus databases. We used the keywords "exergames", "motor education", and "children". The search phrase was obtained using the Boolean operators OR (between the synonyms) and AND (between the descriptors). Two independent evaluators performed the search. Any disagreements were solved by a consensus meeting or decided by a supervisor.

2.2 Inclusion and exclusion criteria

We included peer-reviewed articles that investigated the use of exergames on the acquisition and development of at least one type of locomotor skill or object control both in Physical Education classes and in non-formal educational contexts (clubs, gyms, residences) in school-aged individuals. The exclusion criteria consisted of: (1) opinion articles, reviews, case reports, annals of congresses, books, book chapters, theses, dissertations, and technical reports; (2) games unsuitable for residential or educational use, as well as computer games; (3) research related to the rehabilitation of special groups.

2.3 Data collection process

Data extracted from included studies comprised the following analytical matrices: (1) author, year of publication, and country of the study; (2) purpose of the study; (3) descriptive characteristics of the participants; (4) methodological aspects; (5) results.

2.4 Methodological quality evaluation and epistemological diagnosis

The methodological quality of the studies was evaluated by the Jadad scale [22], which consists of the punctuation of the scores from 11 domains, namely: 1a) the study was reported as randomized; 1b) the randomization was properly performed; 2a) the study was a double-blind trial; 2b) the blinding was properly performed; 3) the sample loss was described. If items 1a, 2a, and 3 were performed, the study got 1 point per item. If items 1b and 2b were observed, the study received another point per item. In the case of items 1b and 2b were not met, the study lost 1 point concerning items 1a and 2a, respectively. On this scale, the scores ranged

from 0 to 5. Studies with scores equal to or lower than 3 points were considered at a high risk of bias. Two independent and qualified researchers applied this instrument. A third author was consulted in case of any divergence.

The epistemological evaluation of the surveyed material occurred through the Systematization for Research Approaches in Sports Sciences (SRASS) instrument [23]. The SRASS aims to determine the epistemic approaches of studies regarding their guiding paradigms (empirical-experimental paradigm; critical-dialectic paradigm; hermeneutic-phenomenological paradigm); nature of the study (intervention study; cross-sectional study; case study; laboratory study); support theories (theories of human movement; game theories; theories of sports training; theories of didactics applied to sport) and subareas of linkage to Sport Sciences (Sports Medicine; Biomechanics applied to Sport; Sport Psychology; Sport Pedagogy); Sociology of Sport; History of Sport; Philosophy of Sport; Sport and Health; Sport for Special Groups; Sport and Media; Sport of Participation) [23, 24].

3. Results

In total, 120 studies were found following the proposed research methodology (Web of Science = 12; MedLine via PubMed = 17; ScienceDirect = 71; Scopus = 20). After using the selection criteria, 17 studies were included (**Figure 1**).

Table 1 shows the descriptive characteristics of the studies included in the present review. The year of publication of the studies ranged from 2012 to 2020. The sample size in each group (intervention and control) ranged from 5 to 557 participants. The samples included both girls and boys, except the study by EbrahimiSani et al. [26] that included only girls. The total number of participants was 2,631 (1,338 in the intervention group and 1,293 in the control group). The age of the participants ranged from 4 to 14 years old.

n: sample size; IG: intervention group; CG: control group; ♀: female; ♂: male; DCD: developmental coordination disorder.

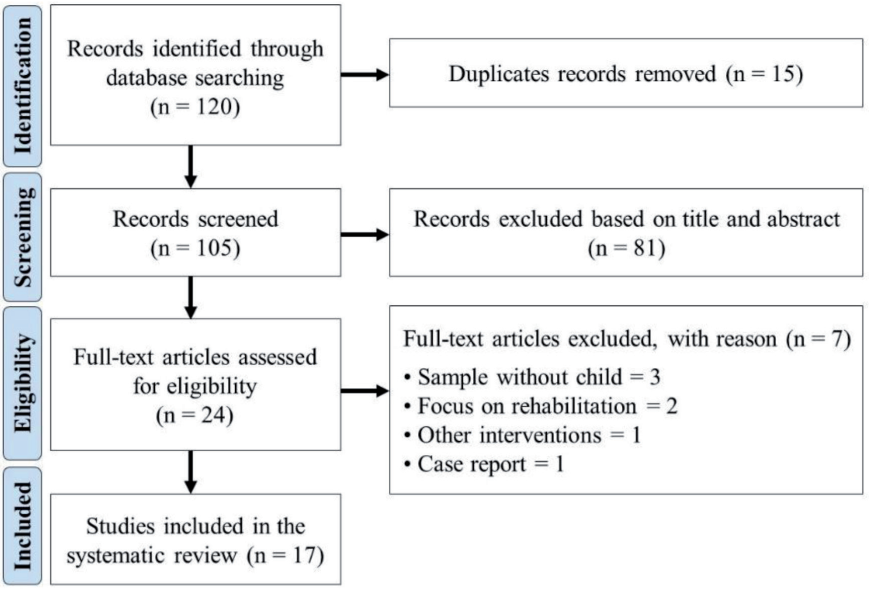

Figure 1.
Flow chart of the included studies.

Author and year	Country	Groups (n)	Age (years)	Sex	Participants' profile
Barnett et al., 2015 [25]	Australia	95	4 to 8 6.2 ± 0.95	♀♂	Neurotypical
EbrahimiSani et al., 2020 [26]	Iran	IG: 20 CG: 20	7 to 10 8.9 ± 1.07	♀	DCD
Edwards et al., 2016 [27]	Australia	IG: 11 CG: 19	6 to 10	♀♂	GI: autism GC: neurotypical
Gao et al., 2018 [28]	USA	IG: 20 CG: 36	4.45 ± 0.46	♀♂	Neurotypical
Johnson et al., 2015 [29]	Australia	IG: 15 CG: 14	6 to 10 7.9 ± 1.5	♀♂	Neurotypical
Lwin and Malik, 2012 [30]	Singapore	IG: 557 CG: 555	10 to 12	♀♂	Neurotypical
McGann et al., 2019 [20]	Ireland	IG: 20 CG: 20	5 to 7	♀♂	Neurotypical
Medeiros et al., 2018 [31]	Brazil	IG: 6 CG: 5	8 to 10 9.09 ± 0.75	♀♂	DCD
Pope et al., 2015 [32]	USA	G1: 63 G2: 95 G3: 47	8 to 14 11.17 ± 1.1	♀♂	G1: progressive children G2: stable children G3: regressive children
Quintas et al., 2020 [33]	Spain	IG: 226 CG: 191	10 to 12	♀♂	Neurotypical
Rhodes et al., 2017 [34]	Canada	IG: 39 CG: 34	10 to 14	♀♂	Neurotypical
Sheehan and Katz, 2013 [35]	Canada	IG: 21 CG1: 21 CG2: 19	9 to 10	♀♂	Neurotypical
Smits-Engelsman et al., 2017 [36]	South Africa	G1: 9 G2: 9	6 to 10	♀♂	G1: DCD (dyspraxia) G2: neurotypical
Smits-Engelsman et al., 2020 [37]	South Africa	G1: 33 G2: 28	6 to 12	♀♂	G1: DCD (dyspraxia) G2: neurotypical
Sun, 2012 [38]	USA	IG: 46 CG: 42	9 to 12	♀♂	Neurotypical
Ye et al., 2018 [39]	USA	IG: 135 CG: 115	7 to 9 8.25 ± 0.66	♀♂	Neurotypical
Vernadakis et al., 2015 [40]	Greece	IG: 22 CG1: 22 CG2: 22	6 to 7	♀♂	Neurotypical

Table 1.
Descriptive characteristics of the included studies.

Table 2 presents the methodological characteristics and the main results of the selected studies. The exergames used were Nintendo Wii, Xbox 360 Kinect, and PlayStation. The training frequency varied between 1 to 5 times per week, with a total of 8 to 60 minutes of intervention per week, for 2 to 36 weeks.

Study	Protocol	Volume	Evaluation	Results
Barnett et al. [25]	One hour after school Nintendo Wii® session	1×/week 60 min 6 weeks	A1: TGMD-2 A2: PMSC	A2 ($p < 0.05$)
EbrahimiSani et al. [26]	IG: virtual reality with Xbox 360 Kinect games CG: no intervention	16 sessions 30 min 8 weeks	A1: hand rotation task A2: anticipatory action planning A3: rapid online control	A1 ($p < 0.05$, IG *vs*. CG)
Edwards et al. [27]	IG: Xbox 360 at home with specific mini-games (e.g., baseball, golf, tennis, table tennis, soccer, bowling, volleyball, and football) CG: Xbox 360 during school lunchtimes	IG: 3×/week 45–60 min 2 weeks CG: 1×/week 50 min 6 weeks	A1: TGMD-3 A2: PMSC	IG and CG without significant difference pre- and post-intervention
Gao et al. [28]	IG: exergaming (Wii or Xbox Kinect) Dance for Kids, Wii Nickelodeon Fit, Kinect Just Dance for Kids CG: no structured PA	8 weeks 20 min	A1: PSPCSA A2: TGMD-2 A3: ActiGraph GT9X Link accelerometers	A1 ($p < 0.05$, IG *vs*. CG)
Johnson et al. [29]	IG: Xbox Kinect games (Specific mini-games: baseball, golf, tennis, table tennis, soccer, bowling, volleyball, and football)	1×/week 50 min 6 weeks	A1: TGMD-3 A2: PMSC	A1 and A2: no significant difference
Lwin and Malik [30]	IG: PE lesson with Wii active video games (DDR, Wii tennis, and Wii boxing) CG: PE lesson without Wii	1×/week 8–10 min 6 weeks	A1: attitude scale A2: subjective norm scale A3: perceived behavioral control scale A4: intention scale A5: exercise behavior questionnaire	A1 ($p < 0.001$, IG *vs*. CG) A2 ($p < 0.05$, IG *vs*. CG) A5 Strenuous exercise ($p < 0.05$, IG *vs*. CG)
McGann et al. [20]	IG: Kinect® (Slide Ball, Hop Ball, Jump Ball, Skip Attack) CG: commercial exergames	1×/week 60 min 8 weeks	TGMD-2	$p < 0.001$, IG *vs*. CG
Medeiros et al. [31]	IG: XBOX-360 Kinect Sports 1 (soccer and athletics), Kinect Sports 2 (skiing, tennis, and shooting), Kinect adventure CG: no playing	2×/week 45 min 9 weeks	MABC-2	$p < 0.05$, IG *vs*. CG
Pope et al. [32]	6 DDR stations were set up each with 2 master dance pads connected to a PlayStation Gaming System	1×/week 30 min 18 weeks	Decisional balance	$p < 0.05$, G1, G2, and G3 post-intervention

Study	Protocol	Volume	Evaluation	Results
Quintas et al. [33]	IG: Just Dance Now + MDA CG: danced by imitating the teacher live	12 sessions 9 hours 4 weeks	A1: Motivation A2: Dispositional flow A3: Basic psychological needs A4: Rhythmic Motor Skill A5: Commitment to and behavior toward learning	A1, A2, A3, A4, and A5: no significant difference after intervention
Rhodes et al. [34]	IG: exergame bike in Sony Playstation3® CG: stationary bike in front of a TV	3×/week 30 min 12 weeks	Weekly bike use recorded in a logbook	$p < 0.05$, IG *vs*. CG
Sheehan and Katz [35]	IG: iDance™ + Wii Fit™ Plus + XR-Board™ + Lightspace™ Play Wall CG1: PE class geared toward ABC improvement CG2: typical PE curriculum class	4–5×/week 34 min 6 weeks	Balance tests on the HUR BT4™ platform	$p < 0.05$, IG and CG1
Smits-Engelsman et al. [36]	G1 and G2: active Nintendo Wii Fit gaming on the balance board	2×/week 20 min 5 weeks	A1: FSM A2: 10 × 5 meter sprint A3: 10 × 5 meter slalom A4: Balance and running speed & agility subtests of the BOT2	A1, A2, and A3 ($p < 0.05$, IG and CG) A4 ($p < 0.05$, G1 *vs*. G2)
Smits-Engelsman et al. [37]	Wii ski game	2×/week 30 min 10 weeks	MABC-2	$p < 0.05$, G2 *vs*. G1
Sun [38]	IG: exergaming (Cateye Gamebikes, Xavix Boxing, 3-kick, Dog Fight Flight simulators, Nintendo Wiis, DDR, Gamercize activities, and XrBoards) CG: traditional fitness-education unit	2×/week 30 min 4 weeks	A1: in-class PA level by RT3 accelerometers A2: situational interest scale A3: initial interest A4: situational interest change	A2 ($p < 0.05$, IG *vs*. CG)
Ye et al. [39]	IG: exergaming (Kinect Ultimate Sports, Just Dance, Wii Sports, and Wii Fit) and PE program CG: only PE	2×/week 25 min 36 weeks	A1: Motor skill competence (MSC) A2: Health-related fitness (HRF)	A2 ($p < 0.05$ IG *vs*. CG)

Study	Protocol	Volume	Evaluation	Results
Vernadakis et al. [40]	IG: Xbox Kinect games CG1: typical FMS training program CG2: no structured training program	2×/week 30 min 8 weeks	A1: TGMD-2 A2: PA enjoyment scale	A1 ($p < 0.05$, IG and CG1 *vs*. CG2) A2 ($p < 0.05$, IG *vs*. CG1 and CG2)

IG: intervention group; CG: control group; A: assessment; DDR: Dance Dance Revolution; TGMD-2: Test of Gross Motor Development-2nd Edition; TGMD-3: Test of Gross Motor Development-3; MABC-2: Movement Assessment Battery for Children-Second Edition; PE: Physical Education; PA: physical activity; ABC: agility, balance, and coordination; FSM: Functional Strength Measure; BOT2: Bruininks Oseretsky test of motor proficiency 2; MDA: Mechanics-Dynamics-Esthetics; PSPCSA: Pictorial Scale of Perceived Competence and Social Acceptance; PMSC: Pictorial Scale of Perceived Movement Skill Competence; FMS: fundamental motor skills.

Table 2.
Methodological and outcomes data extracted from the studies.

Studies	1a	1b	2a	2b	3	Score
Medeiros et al. [31]	1	1	1	1	1	5
Rhodes et al. [34]	1	1	1	1	1	5
EbrahimiSani et al. [26]	1	1	1	−1	1	3
Vernadakis et al. [40]	1	1	0	0	0	2
Barnett et al. [25]	1	−1	0	0	1	1
Gao et al. [28]	0	0	0	0	1	1
McGann et al. [20]	1	−1	0	0	1	1
Quintas et al. [33]	0	0	0	0	1	1
Sheehan and Katz [35]	1	−1	0	0	1	1
Smits-Engelsman et al. [36]	0	0	1	−1	1	1
Smits-Engelsman et al. [37]	0	0	0	0	1	1
Ye et al. [39]	0	0	0	0	1	1
Johnson et al. [29]	1	−1	1	−1	0	0
Lwin and Malik [30]	0	0	0	0	0	0
Pope et al. [32]	0	0	0	0	0	0
Edwards et al. [27]	1	−1	0	0	0	0
Sun [38]	0	0	0	0	0	0

1a: randomized study; 1b: adequate randomization; 2a: double-blind study; 2b: proper blinding; 3: description of the sample loss.

Table 3.
Methodological quality evaluation through the Jadad scale.

The methodological quality evaluation is shown in **Table 3**. Only two studies [31, 34] presented a low risk of bias.

Table 4 shows the epistemological characteristics of the studies according to the STRASS criteria.

Study	Paradigm	Nature of the study	Theoretical bases of support	Linking sub-areas
Barnett et al. [25]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
EbrahimiSani et al. [26]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Edwards et al. [27]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Gao et al. [28]	Empirical-experimental	Intervention study	Theories of Human Movement/Theories of Sports Training	Sport Psychology/Sport and Health
Johnson et al. [29]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Lwin and Malik [30]	Empirical-experimental	Intervention study	Theories of Human Movement/Theories of Sports Training	Sport Psychology/Sport and Health
McGann et al. [20]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Medeiros et al. [31]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Pope et al. [32]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Quintas et al. [33]	Empirical-experimental	Intervention study	Theories of Human Movement/ Theories of Didactics applied to Sport	Sport Psychology/Sport Pedagogy
Rhodes et al. [34]	Empirical-experimental	Intervention study	Theories of Human Movement/Theories of Sports Training	Sport Psychology/Sport and Health
Sheehan and Katz [35]	Empirical-experimental	Intervention study	Theories of Sports Training/ Theories of Didactics applied to Sport	Sport Pedagogy/Sport and Performance
Smits-Engelsman et al. [36]	Empirical-experimental	Intervention study	Theories of Sports Training	Sport and Performance
Smits-Engelsman et al. [37]	Empirical-experimental	Intervention study	Theories of Human Movement/Theories of Sports Training	Sport and Performance
Sun [38]	Empirical-experimental	Intervention study	Theories of Human Movement/ Theories of Sports Training/ Theories of Didactics applied to Sport	Sport and Health/ Sport Psychology/Sport Pedagogy
Ye et al. [39]	Empirical-experimental	Intervention study	Theories of Human Movement/Theories of Sports Training	Sport Psychology/Sport and Health
Vernadakis et al. [40]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology

Table 4.
Epistemological characteristics of the studies.

4. Discussion

This study aimed to identify, through a systematic review, the ways of using exergames in the motor education processes of school-aged children and to diagnose the epistemic state of this use in the context of Sport Sciences. Technically, exergames gather the main dimensions of virtual realities: interaction, involvement, and immersion. The interaction is related to the environment's ability to respond to user actions interactively through devices. Some devices can naturally capture users' movements. The involvement is the ability to maintain the user's attention, seeking to explore their different senses, keeping the user attracted and motivated to remain in the environment. Immersion refers to the ability to make the user feel present in the simulated environment, seeking to distance them from the real environment [18].

A dominant feature of the investigations raised on exergames in our study concerns the fact that most of them focused on samples of neurotypical infants. Neurotypical individuals are those who do not fit the autism spectrum, exhibiting linguistic, sensorimotor, affective, and cognitive aspects consistent with those expected for their chronological age [41]. Eleven of the included studies [20, 25, 28–30, 33–35, 38–40] exemplify this trend. Conversely, four included studies [26, 31, 36, 37] analyzed the motor behaviors of children with developmental coordination disorder. The other two studies included, as target subjects, groups of neurotypical and autistic individuals [27] and young people in different stages of motor performance [32].

In summary, it is noted that the dominant neurological characteristic of the investigated subjects refers to neurotypical people, that is, situated within frames considered normal. Contrariwise, neurodivergent or neuroatypical analyzes are in the minority. Moreover, all authors focused on sample groups of infants of both sexes, except EbrahimiSani et al. [26], who prioritized only girls. It is concluded then, in this regard, that the investigations do not privilege the masculine gender over the feminine and vice versa. Still with respect to the sample groups, it is reiterated that the samples were heterogeneous in terms of the number of individuals analyzed, chronological ages, and levels of biological maturation.

Another demographic item to be highlighted is the fact that the investigations are distributed by teams of researchers located in different countries. This means that the theme of the effects of exergames on the acquisition and development of motor skills of schoolchildren has a global connotation.

In terms of the methodological characteristics of the investigations, despite the different training volumes and motor stimuli applied, in almost all studies some type of significant result was obtained from the intervention groups when compared to the control groups. At first, this means that exergames may have positive effects on the gross motor skills and physical fitness levels of children with different levels of training. Only one study [33] showed no change in any variable. However, such gains should be viewed with caution, as it is not possible to confirm whether they will continue, and in what proportion, as the infant's biological maturation progresses and the training status changes.

This diagnosis is reinforced when it is observed that, among the 17 selected studies, only two [31, 34] were considered to be of high theoretical and methodological quality. Hence, they correspond to those of greater scientific credibility. In compensation, 15 investigations received a rating of three or less on the Jadad scale [22], which denotes compromises in their quality in terms of scientificity. Thus, they are research with coherence, consistency, objectivity, and control of subjectivity subject to criticism. As a result, the verisimilitude of the conclusions they announce must be interpreted with caution [42].

To paraphrase Miller [43], situations of this nature are relatively usual when a given object of study is still recent, in the sense that the scientific community to address it is still in the early stages of theoretical problematization. Consequently, the demarcations of the object have little depth, as well as the investigative horizons considered more pertinent in the medium and long terms.

Regarding the epistemological profile of the studies surveyed, it can be seen that, in full, all consisted of empirical-experimental intervention studies. Research with this bias has, as a guiding axis, the exposure of individuals to certain stimuli to verify their random impacts on one or more pre-established variables. In this type of conception, the researcher pre-understands that certain factors are hypothetically capable of engendering transformations in structural elements of the object. In the case of the present study, it is reasonable to conclude that researchers in exergames assume that such a class of games is capable of influencing the biopsychic construction of the motor skills of school-aged individuals. Hence the need for them to seek reliable evidence on such a process [24, 42].

The conceptual basis adopted to support the selected investigations refers almost exclusively to the Theories of Human Movement with an emphasis on Sport Psychology of a behavioral nature. However, it was possible to identify, in some of them, the existence of interfaces with the areas of Sport Pedagogy, Sport and Performance, and Sport and Health. Mediating this junction are the theories of Sports Training and Didactics. As a complement, we reiterate that no study mentioned Game Theories, which are among the classic bodies of knowledge of Physical Education and Sport Sciences.

The previous observation shows two contexts that are interconnected. The first goes back to the detection that, despite behavioral Sport Psychology being the Sports Science sub-area to endorse most of the inventoried works, it is possible to perceive the search for an incipient interdisciplinary dialog with the other mentioned theoretical fields. On the other hand, and this is the second consideration, Sports Training, and Didactics, under the aegis of Sport Pedagogy, Sport and Health, and Sport and Performance, constitute disciplines that go back to the structuring nucleus originating from Physical Education and Sports Science [24]. Therefore, it can be seen that, given the emergence of the relationship between exergames and the development of motor skills in childhood, given that it is a relatively recent object of study, a return to the knowledge bases that support the epistemic tradition of Physical Education and Sport Sciences is outlined. In terms of Theory of Knowledge, attitudes like these are consistent with the notion called Fundationalism, which alludes to the search for theoretical support for new ideas in knowledge that history has endorsed and endorse as legitimate in the flow of time [44].

The present study has some limitations. The first concerns the selection of articles from four electronic databases. Although the investigated databases catalog a vast number of scientific journals worldwide, some articles published in other journals that address this issue may not have been found. Studies from a larger number of search engines could enrich the analysis and discussions.

5. Conclusions

The present study allows the announcement of some conclusions. Effectively, the use of exergames by school-aged children can promote an increase in motor skills both in locomotion and in object control. Their physical fitness levels are also capable of improving. However, the magnitude and duration of these increments remain inconclusive.

In epistemological terms, the state of knowledge of the productions related to the theme is in an embryonic state. Furthermore, the quality of the articles exhibits theoretical and methodological weaknesses that must be overcome. Investigations of an empirical-experimental nature focused on intervention studies are hegemonic. At the conceptual level, the theories of Sports Training, Didactics, and Human Movement have been chosen to provide the theoretical foundation, referring to the existence of an interdisciplinary intersection, in the field of Sport Sciences, between Sport Psychology, Sport Pedagogy, Sport and Performance, and Sport and Health.

Based on this diagnosis, it is urgent to affirm that, for example, research that opts for alternative methodological designs is still necessary, such as case reports, cross-sectional studies, longitudinal studies, and even conceptual essays. In the case of Sports Science sub-areas, it is necessary to approach the subject according to other perspectives. As an option, we suggest Biomechanics applied to Sport, Sports Medicine, Sport Sociology, and Sport Philosophy.

Conflict of interest

The authors declare no conflict of interest.

Author details

Dirceu Ribeiro Nogueira da Gama[1*], Andressa Oliveira Barros dos Santos[1], João Gabriel Miranda de Oliveira[1], Juliana Brandão Pinto de Castro[1] and Rodrigo Gomes de Souza Vale[1,2]

1 Postgraduate Program in Exercise and Sport Sciences, Rio de Janeiro State University, Rio de Janeiro, Brazil

2 Laboratory of Exercise Physiology, Estácio de Sá University, Cabo Frio, RJ, Brazil

*Address all correspondence to: dirceurng@gmail.com

References

[1] Gallahue DL, Ozmun JC, Goodway JD. Understanding motor development: Infants, children, adolescents, adults. 7th ed. Boston, MA: McGraw-Hill; 2011. 480 p.

[2] Palmer KK, Chinn KM, Robinson LE. The effect of the CHAMP intervention on fundamental motor skills and outdoor physical activity in preschoolers. Journal of Sport and Health Science. 2019;8(2):98-105. DOI: 10.1016/j.jshs.2018.12.003

[3] Mazzoli E, Koorts H, Salmon J, Pesce C, May T, Teo WP, Barnett LM. Feasibility of breaking up sitting time in mainstream and special schools with a cognitively challenging motor task. Journal of Sport and Health Science. 2019;8:137-148.

[4] Hands B, Larkin D, Parker H, Straker L, Perry M. The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents. Scandinavian Journal of Medicine & Science in Sports. 2009;19(5):655-663. DOI: 10.1111/j.1600-0838.2008.00847.x

[5] Haywood KM, Getchell N. Lifespan motor development. 5th ed. Champaign, IL: Human Kinetics; 2009. 408 p.

[6] Ulrich DA. The test of gross motor development. 2nd ed. Austin, TX: PRO-ED; 2000. 60 p.

[7] Adams J, Veitch J, Barnett L. Physical activity and fundamental motor skill performance of 5-10 year old children in three different playgrounds. International Journal of Environmental Research and Public Health. 2018;15(9):1896. DOI: 10.3390/ijerph15091896

[8] Logan SW, Ross SM, Chee K, Stodden DF, Robinson LE. Fundamental motor skills: A systematic review of terminology. Journal of Sports Sciences. 2017;36(7):781-796. DOI: 10.1080/02640414.2017.1340660

[9] Lubans DR, Morgan PJ, Cliff DP, Barnett LM, Okely AD. Fundamental movement skills in children and adolescents: review of associated health benefits. Sports Medicine. 2010;40(12):1019-1035. DOI: 10.2165/11536850-000000000-00000

[10] Goodway JD, Branta CF. Influence of a motor skill intervention on fundamental motor skill development of disadvantaged preschool children. Research Quarterly for Exercise and Sport. 2003;74(1):36-46. DOI: 10.1080/02701367.2003.10609062

[11] Pauer TP. O Desenvolvimento motor em jovens atletas de alto nível. São Paulo: Publishing House Lobmaier; 2005. 238 p.

[12] Webster EK, Martin CK, Staiano AE. Fundamental motor skills, screen-time, and physical activity in preschoolers. Journal of Sport and Health Science. 2019;8(2):114-121. DOI: 10.1016/j.jshs.2018.11.006

[13] Zeng N, Johnson SL, Boles RE, Bellows LL. Social-ecological correlates of fundamental movement skills in young children. Journal of Sport and Health Science. 2019;8(2):122-129. DOI: 10.1016/j.jshs.2019.01.001

[14] Mitchell B, McLennan S, Latimer K, Graham D, Gilmore J, Rush E. Improvement of fundamental movement skills through support and mentorship of class room teachers. Obesity Research & Clinical Practice. 2013;7(3):e230-e234. DOI: 10.1016/j.orcp.2011.11.002

[15] Brien WO, Belton S, Issartel J. Fundamental movement skill proficiency amongst adolescent

youth. Physical Education and Sport Pedagogy. 2016;21(6):557-571. DOI: 10.1080/17408989.2015.1017451

[16] Hardy LL, Barnett L, Espinel P, Okely AD. Thirteen-year trends in child and adolescent fundamental movement skills. Medicine & Science in Sports & Exercise. 2013;45(10):1965-1970. DOI: 10.1249/MSS.0b013e318295a9fc

[17] Brian A, Pennell A, Taunton S, Starrett A, Howard-Shaughnessy C, Goodway JD, et al. Motor competence levels and developmental delay in early childhood: A multicenter cross-sectional study conducted in the USA. Sports Medicine. 2019;49(10):1609-1618. DOI: 10.1007/s40279-019-01150-5

[18] Araújo JGE, Batista C, Moura DL. Exergames in Physical Education: A systematic review. Movimento. 2017;23(2):529-542. DOI: 10.22456/1982-8918.65330

[19] Hulteen RM, Johnson TM, Ridgers ND, Mellecker RR, Barnett LM. Children's movement skills when playing active video games. Perceptual and Motor Skills. 2015;121(3):767-790. DOI: 10.2466/25.10.PMS.121c24x5

[20] McGann J, Issartel J, Hederman L, Conlan, O. Hop Skip Jump Games: The effect of "principled" exergameplay on children's locomotor skill acquisition. British Journal of Educational Technology. 2019;51(3):798-816. DOI: 10.1111/bjet.12886

[21] Urrútia G, Bonfill X. PRISMA declaration: A proposal to improve the publication of systematic reviews and meta-analyses. Med Clin. 2010;135:507-511. DOI: 10.1016/j.medcli.2010.01.015

[22] Jadad AR, Moore RA, Carroll D, et al. Assessing the quality of reports of randomized clinical trials: Is blinding necessary? Controlled Clinical Trials. 1996;17(1):1-12.

[23] Faria Junior AG. Trends of research in Sports Sciences in England, Wales and Brazil (1975-1984): a comparative study. London: University of London Press; 1987. 146 p.

[24] Tubino MJG. As teorias da Educação Física e do Esporte: Uma abordagem epistemológica. São Paulo: Manole; 2002. 70 p.

[25] Barnett LM, Ridgers ND, Reynolds J, Hanna L, Salmon J. Playing Active Video Games may not develop movement skills: An intervention trial. Preventive Medicine Reports. 2015;2:673-678. DOI: 10.1016/j.pmedr.2015.08.007

[26] EbrahimiSani S, Sohrabi M, Taheri H, Agdasi MT, Amiri S. Effects of virtual reality training intervention on predictive motor control of children with DCD – A randomized controlled trial. Research In Developmental Disabilities. 2020 Dec;107:103768. DOI: 10.1016/j.ridd.2020

[27] Edwards J, Jeffrey S, May T, Rinehart NJ, Barnett LM. Does playing a sports active video game improve object control skills of children with autism spectrum disorder? Journal of Sport and Health Science. 2017;6(1):17-24. DOI: 10.1016/j.jshs.2016.09.004

[28] Gao Z, Zeng N, Pope ZC, Wang R, Yu F. Effects of exergaming on motor skill competence, perceived competence, and physical activity in preschool children. Journal of Sport and Health Science. 2018;8(2):106-113. DOI: 10.1016/j.jshs.2018.12.001

[29] Johnson TM, Ridgers ND, Hulteen RM, Mellecker RR, Barnett LM. Does playing a sports active video game improve young children's ball skill competence? Journal of Science and

Medicine in Sport. 2016;19(5):432-436. DOI: 10.1016/j.jsams.2015.05.002

[30] Lwin MO, Malik S. The efficacy of exergames-incorporated Physical Education lessons in influencing drivers of physical activity: A comparison of children and pre-adolescents. Psychology of Sport and Exercise. 2012;13(6):756-760. DOI: 10.1016/j.psychsport.2012.04.013

[31] Medeiros P, Santos JOL, Capistrano R, Carvalho HP, Beltrame TS, Cardoso FL. Effects of exergames in children at risk and significant movement difficulty: a blinded randomized study. Revista Brasileira de Ciências do Esporte. 2018;40(1):87-93. DOI: 10.1016/j.rbce.2018.01.005

[32] Pope ZC, Lewis BA, Gao Z. Using the transtheoretical model to examine the effects of exergaming on physical activity among children. Journal of Physical Activity and Health. 2015;12(9):1205-1212. DOI: 10.1123/jpah.2014-0310

[33] Quintas A, Bustamante JC, Pradas F, Castellar C. Psychological effects of gamified didactics with exergames in Physical Education at primary schools: Results from a natural experiment. Computers & Education. 2020;152:103874. DOI: 10.1016/j.compedu.2020.103874

[34] Rhodes RE, Blanchard CM, Bredin SSD, Beauchamp MR, Maddison R, Warburton DER. Stationary cycling exergame use among inactive children in the family home: a randomized trial. Journal of Behavioral Medicine. 2017;40(6):978-988. DOI: 10.1007/s10865-017-9866-7

[35] Sheehan DP, Katz L. The effects of a daily, 6-week exergaming curriculum on balance in fourth grade children. Journal of Sport and Health Science. 2013;2(3):131-137. DOI: 10.1016/j.jshs.2013.02.002

[36] Smits-Engelsman BCM, Jelsma LD, Ferguson GD. The effect of exergames on functional strength, anaerobic fitness, balance and agility in children with and without motor coordination difficulties living in low-income communities. Human Movement Science. 2017;55:327-337. DOI: 10.1016/j.humov.2016.07.006

[37] Smits-Engelsman B, Bonney E, Ferguson G. Motor skill learning in children with and without Developmental Coordination Disorder. Human Movement Science. 2020;74:102687. DOI: 10.1016/j.humov.2020.102687

[38] Sun H. Exergaming impact on physical activity and interest in elementary school children. Research Quarterly for Exercise and Sport. 2012;83(2):212-220. DOI: 10.1080/02701367.2012.10599852

[39] Ye S, Lee JE, Stodden DF, Gao Z. Impact of exergaming on children's motor skill competence and health-related fitness: A quasi-experimental study. Journal of Clinical Medicine. 2018;7(9):261. DOI: 10.3390/jcm7090261

[40] Vernadakis N, Papastergiou M, Zetou E, Antoniou P. The impact of an exergame-based intervention on children's fundamental motor skills. Computers & Education. 2015;83:90-102. DOI: 10.1016/j.compedu.2015.01.001

[41] Cezar IAM, Maia FA, Mangabeira G, Oliveira AJS, Bandeira LVS, Saeger VSA, et al. A case-control study about autism spectrum disorder and familiar history of mental disorders. J Bras Psiquiatr. 2020;69(4):247-254. DOI: 10.1590/0047-2085000000290

[42] Gadamer HJ. Truth and Method. 2nd ed. London: Continuum; 1989. 637 p.

[43] Miller D. Popper: escritos selectos. Madrid: FCE; 1995. 430 p.

[44] Burdzinski JC. Os problemas do Fundacionismo. Kriterion. 2007;115:107-125.