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Physical Activity and Academic Performance in Children and Preadolescents: A Systematic Review

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Abstract

Physical activity (PA) is an essential means of improving physical and mental health. Its influence on various cognitive aspects such as attention, memory and concentration has been widely studied and it may have a close relationship with academic performance. The objective of this study was to conduct a systematic review of the relationship between doing physical activity and academic performance in schoolchildren. The Web of Science (WOS) repository was used as the main search engine with the selection of longitudinal and experimental studies published in the last five years as the primary criterion. A total sample of 23 research papers was obtained in which intervention programmes based on physical exercise were used to improve academic performance or related parameters. The main findings include the need for PA or physical exercise to be prescribed with adequate volume and intensity parameters, since an insufficient load is not related to academic and/or cognitive performance. Similarly, gross motor tasks and team sports are more effective as they involve greater cognitive demands. The fields of mathematics and logical thinking benefited most.

Keywords: physical activity, sport, academic performance, cognitive performance, schoolchildren

Introduction

Lifestyles in today's society have changed noticeably among children and are becoming less healthy (Donnelly et al., 2017). The time spent by schoolchildren doing physical activity (PA) has diminished in favour of other types of habits such as sedentary digital leisure which is associated with a high use of television, videogames and mobile phones (Gao et al., 2016). This state of affairs is compounded by higher intakes of processed foods with a high calorie component and large amounts of salt, fat and sugars, leading to increased levels of overweight and obesity, together with other related pathologies (Schmidt et al., 2015).

León et al. (2018) define obesity as a non-standard accumulation of body fat that poses a health risk. This pathology has spread among young people, reaching up to 20% in children and adolescents. It has also been shown to be related to other diseases such as diabetes and cholesterol and cognitive problems including low self-esteem, depression and poor academic performance (Schmidt et al., 2015). In addressing this problem, it is essential to increase levels of PA, defined as any body movement involving energy expenditure (Gao et al., 2016). Indeed, several international organisations recommend that young people do at least 60 minutes of PA a day at moderate or vigorous intensity and with a high aerobic component (Mullender-Wijnsma et al., 2015).

In this respect, Van den Berg et al. (2016) show that doing physical activity and sport generates myriad benefits at a multi-factorial level. In physical terms, higher levels of PA are known to be associated with better body composition, greater bone mineral density and higher insulin sensitivity. Its cognitive benefits have also been widely demonstrated, as an active lifestyle helps to reduce anxiety and stress and enhances self-esteem, attention span and executive functions (Donnelly et al., 2017; Mullender-Wijnsma et al., 2016). In particular, recent studies suggest that doing sport helps to improve academic performance at various educational levels (Krafft et al., 2014).

Similarly, educational failure has also become another major problem for school-age young people, which is why it is advantageous to promote an active lifestyle that indirectly improves academic performance (Mullender-Wijnsma et al., 2015). More specifically, the impact of PA has been evidenced in certain factors influencing academic performance, such as memory, attention span and executive functions (Donnelly et al., 2017), due to the reduction brought about by exercise in cortisol concentrations (a hormone associated with a lower attention span), the production of endorphins in order to create attitudes more conducive to learning and better blood supply to the brain, which enhances the stimulation of neurotrophic factors (Krafft et al., 2014).

Some recent studies have explored this relationship and have yielded significant results. Howie et al. (2015) examined the effect of active break times during regular classes on the executive functions and mathematical performance of schoolchildren, finding that sufficiently lengthy PA led to an improvement in them (Ma et al., 2014). By contrast, studies such as those by Donnelly et al. (2017) and Tarp et al. (2016) indicated, through longitudinal studies, that PA was not related to school performance. This standpoint underscores the need to conduct a review of the existing literature on this subject, especially in longitudinal and experimental research, since opposing and contradictory results are found, which means that greater clarity is called for.

Therefore, the objective of the study was to conduct a systematic review of the scientific literature addressing the impact of doing PA on academic performance in preadolescent young people through longitudinal and experimental studies.

Methodology

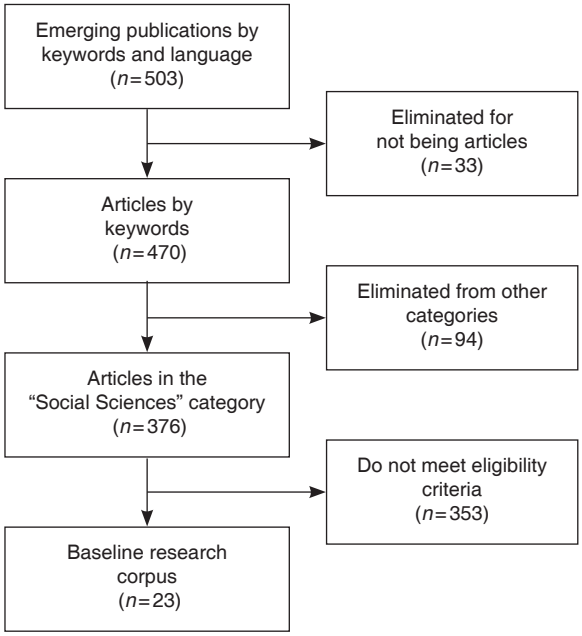
This study followed the PRISMA statement guideline for reporting systematic reviews in order to ensure appropriate structure and development of the paper (Hutton et al., 2015).

Search strategy and procedure

The database used to carry out the proposed systematic review was Web of Science (WOS). The SCOPUS search engine was also used to cross-check the information retrieved from the main database. The review was conducted in July 2018, analysing studies addressing physical fitness and academic performance in school-age children. The search period was from 2014 to 2018, using "Physical activity", "Academic performance" and "Children" as keywords and "and" as the Boolean operator. In the refinement of the search, all the publications in English from the "Web of Science Core Collection" in the "Social Sciences" research domain were considered. Following these guidelines, 470 research papers were obtained.

The inclusion criteria used to specify the research papers that would make up the study sample were: (1) Scientific studies presenting PA and the academic performance of students as variables; (2) Articles using a longitudinal design; (3) Research showing statistical results that allow the analysis of the study variables; (4) Publications subject to peer review.

Figure 1
Flowchart of the selection of the baseline research corpus



Scientific literature population and sample

The population of scientific articles set for this study was 503 documents retrieved from the WOS data repository. The sample making up the baseline corpus of this systematic review corresponds to 23 scientific publications, considered after the eligibility and codification criteria had been applied. (Figure 1)

Results

This section displays the descriptive results of the selected studies ($n=23$) that address the improvement of academic performance through physical activity.

Evaluation of the scientific output

Using the search procedure and strategy, a total of 376 scientific research articles on the influence of PA on academic performance during the period 2014-2018 were registered in WOS considering Social Sciences as the main research area. This accounted for 6.11% ($n=24$) of the global count of scientific literature output on this topic in WOS. A review of the total output points to an upward trend since 2014, peaking in 2017 with 100 publications. There was a decline in 2018 with 51 scientific papers, although it should be noted that this annual cycle was still open when the review was conducted, in July 2018. As for the research corpus, output rose between 2014 and 2016 and then flatlined in 2017 and 2018 with three publications in each period. This confirmed that there was a fall in publications examining the influence of doing PA on the academic performance of school-age children in the last two years.

Results of the studies selected for systematic review

Table 1 shows the results obtained after the systematic review using the aforementioned search criteria and analysing the association between doing PA and academic performance in school-age girls and boys and preadolescents. A total participation of 7,160 subjects between the ages of 7 and 15 was obtained by aggregating the sample of each paper. All of them took part in various kinds of longitudinal studies with some type of control in order to confirm causal relationships between the different forms of doing PA, academic performance and various factors related to it such as attention span, executive functions and cognitive performance. The following coding was used to extract the information in the systematic review: (1) Authors and year of publication; (2) Methodological design of the study; (3) Sample and breakdown of the study into experimental group (EG) and control group (CG); (4) Minimum, maximum and mean age; (5) Basic description of the intervention carried out in terms of load and volume of exercise; (6) Length of the intervention; (7) Dependent variables considered in the longitudinal study (academic performance, attention, etc.); (8) Instruments used to assess dependent variables; and, (9) Conclusions and findings.

Table 1
Baseline corpus of articles addressing doing physical activity and academic performance in children

Authors and year	Design	Sample (E-C)	Age (min-max.)	Intervention	Length	Variables	Instrument	Conclusions
Ardoy et al. (2014)	Randomised controlled intervention	67 (26-41)	13,64 (12-14)	4 PE sessions (55 min) per week and 4 sessions (55 min) at higher intensity	4 months	Cognitive performance Academic performance	IIGF-M Term grades	The schoolchildren who did 4 sessions of PA at higher intensity improved academic performance, although cognitive performance was not improved.
Beck et al. (2016)	Cluster-randomised intervention	165 (110-55)	7.5 (7-8)	Motor-enriched mathematical teaching (60 min 3 times a week)	6 weeks	Mathematical performance Cognitive performance	Ad hoc test (30 items) CANTAB	Greater improvements in subjects with lower maths performance and who perform gross motor tasks. Maintained for up to 8 weeks.
Bugge et al. (2018)	Quasi-experimental study with control group	1181 (680-501)	8.33 (8-9)	Triple Physical Education time (from 90 min to 270 min per week)	6 years	Academic performance	Danish system national test	The schoolchildren were not affected by the intervention, although health parameters such as cardio-respiratory fitness did improve.
Bunketorp et al. (2015)	Quasi-experimental design with control group	349 (182-167)	9.95 (9-11)	2 weekly extracurricular PA sessions lasting 30-45 min	4 years	Academic performance Emotion and behaviour	National results SDQ	Academic performance increased, student behaviour improved and the level of wellbeing increased, especially in girls.
Chen et al. (2017)	Single-blind randomised control trial	66 (33-33)	14.18 (13-16)	Multi-component exercise 3 days a week for 50 min at moderate intensity	12 weeks	Meta-cognitive tasks	TOL	Meta-cognitive capacity was improved in obese adolescents, entailing the capacity to plan and process spatial information.
Donnelly et al. (2017)	Cluster-randomised intervention	584 (316-268)	8.1 (7-9)	Inclusion of 10 minutes of PA per morning and afternoon lesson (100 min/week)	3 years	Academic performance	WIAT-III	The A+PAAC programme neither improved nor reduced academic performance, although it did generate physical and mental health benefits.
Duncan y Johnson (2014)	Cross-longitudinal study	18 (18-NA)	9.8 (8-11)	Fill in WRAT 4 after 20 min at 50% and 75% of HRR on a cycling ergometer	20 min	Academic performance	WRAT 4	Moderate intensity exercise on a cycling ergometer improved reading but not arithmetic. The improvements were not associated with greater intensity.
Fedewa et al. (2015)	Randomised controlled intervention	460 (156-304)	NA (school-age)	Inclusion of 20 min of PA per day (5 times a week) by means of movement card games	8 months	Fluid intelligence Academic performance	SPM National results	The intervention did not improve fluid intelligence. There were improvements in performance in mathematics but not in reading.

Note. Concepts. PA: Physical Activity; PE: Physical Education; NA: Not available; GC: Control group; GE: Experimental group. Instruments: BOSST: Behavioral Observation of Students in Schools Tool; CANTAB: Cambridge Neuropsychological Test Automated Battery; CBB: Costage Brief Battery; NYSTP: New York State Testing Program; d2TA: d2 Test of Attention; LDST: Letter Digit Substitution Test; NDET: Norwegian Directorate for Education and Training; RIAS: Reynolds Intellectual Assessment Scales; IGF-M: Test de Inteligencia Factorial; TOL: Tower of London-Drexel task; TMT: Trail-Making Test; TEIQque-SF: Trait and Emotional Intelligence Questionnaire Short Form; SPM: Standard Progressive Matrices; SDQ: Strengths and Difficulties Questionnaire; WIAT-III: Wechsler Individual Achievement Test-Third Edition; WRAT 4: Wide Range Achievement Test.

Table 1 *(Continuation)*
Baseline corpus of articles addressing doing physical activity and academic performance in children

Authors and year	Design	Sample (E-C)	Age (min.-max.)	Intervention	Length	Variables	Instrument	Conclusions
Gao et al. (2016)	One group pre- and post-test repeated measures	95 (95-NA)	10.31 (10-11)	50 min. weekly school PA + 20 min. daily break based on active videogames	6 weeks	Academic effort On-task behaviour	Validated scale Direct observation	The intervention programme based on active videogames at school slightly improved academic effort and behaviour.
Howie et al. (2015)	Cross-longitudinal study	96 (96-NA)	NA (9-12)	5, 10 and 20 min. of moderate intensity classroom PA breaks	5/10/20 min	Executive functions Memory Academic performance	TMT Digit Recall Maths test	5 minutes of PA did not generate cognitive improvements, although 10 and 20 minutes did improve maths performance. The programme did not negatively affect executive functions.
Krafft et al. (2014)	Randomised controlled intervention	43 (24-19)	9.8 (7-11)	Moderate-intensity aerobic exercise 40 minutes per day (5 days a week)	8 months	Cognition (planning, attention, etc.)	CAS	Physical exercise improved circulation in the anterior cortex in overweight children (decreased supply and greater efficiency) and greater cognitive activation.
Lind et al. (2018)	Randomised controlled intervention	931 (838-93)	11.9 (10-12)	Two 45-minute exercise sessions per week with the FIFA 11 programme (2 football sessions)	11 weeks	Cognitive performance	CBB	The FIFA 11 programme based on high-intensity football games had positive effects on cognitive performance (attention, alertness and working memory).
Ma et al. (2014)	Cross-longitudinal study	44 (44-NA)	NA (school-age)	5 days with "FUNterval" activities (4 min. high intensity PA breaks)	3 weeks	Behaviour observed in the classroom	BOSST	The FUNtervals programme reduced the time spent off-task (motor, passive, and verbal behaviour).
Mullender-Wijnsma et al. (2015)	Randomised controlled intervention	81 (20-61)	8.2 (7-9)	Language and maths activity with 10-15 min. physical exercise 3 times a week	22 weeks	Time spent on tasks	Time spent on tasks	Active language and mathematics activities improved time-on-task in both groups, albeit lower in socially disadvantaged children.
Mullender-Wijnsma et al. (2016)	Randomised controlled intervention	499 (249-250)	8.1 (7-9)	Active maths and language classes from 20 to 30 min. 3 times a week	44 weeks over 2 years	Academic performance in language and mathematics	Global reading and maths ability tests	Doing PA in mathematics and language improved performance in these fields due to the level of motivation and the inherent benefits of PA in cognition.

Note. Concepts. PA: Physical Activity; PE: Physical Education; NA: Not available; GC: Control group; GE: Experimental group. Instruments: BOSST: Behavioral Observation of Students in Schools Tool; CANTAB: Cambridge Neuropsychological Test Automated Battery; CBB: Costage Brief Battery; NYSTP: New York State Testing Program; d2TA: d2 Test of Attention; LDST: Letter Digit Substitution Test; NDET: Norwegian Directorate for Education and Training; RIAS: Reynolds Intellectual Assessment Scales; IGF-M: Test de Inteligencia Factorial; TOL: Tower of London-Drexel task; TMT: Trail-Making Test; TEIQque-SF: Trait and Emotional Intelligence Questionnaire Short Form; SPM: Standard Progressive Matrices; SDQ: Strengths and Difficulties Questionnaire; WIAT-III: Wechsler Individual Achievement Test-Third Edition; WRAT 4: Wide Range Achievement Test.

Table 1 *(Continuation)*
Baseline corpus of articles addressing doing physical activity and academic performance in children

Authors and year	Design	Sample (E-C)	Age (min.-max.)	Intervention	Length	Variables	Instrument	Conclusions
Phillips et al. (2015)	Pre-experimental intervention	72 (36-36)	14.1 (14-15)	Vigorous aerobic PA circuit with 9 activities and a total duration of 20 min	20 min	Maths performance	NYSTP	The mean score in mathematical performance was increased in the group that performed vigorous PA after 30 min. (not at 45 min).
Quinto and Klausen (2016)	Randomised controlled intervention	925 (554-371)	ND (11-13)	HIT training for 20 min. 2 times a week	2 years	Academic performance	Annual grade score	The effect of the intervention was not significant in most fields related to academic performance, and in some cases was even negative.
Resaland et al. (2016)	Cluster-randomised controlled intervention	57 (28-29)	10.2 (10-11)	90 min. a wk. of school PA + active breaks per lesson + 10 min. of home PA	7 months	Academic performance in English, language and mathematics	NDET	No statistical differences in academic performance are shown, although the arithmetic score improved in those with poorest performance at baseline.
Riley et al. (2016)	Randomised controlled intervention	240 (142-98)	11.1 (11-12)	Mild-moderate PA performance in maths lessons (3 x 60 min)	6 weeks	Academic performance in mathematics	Field score + teacher scale	PA levels increase without sacrificing academic performance, which improved through task resolution and observed behaviour.
Ruiz-Ariza et al. (2018)	Randomised controlled intervention	190 (87-103)	13.32 (12-15)	Mild intensity PA performance (walking) through Pokémon Go (40 min a day)	8 weeks	Cognitive performance Emotional intelligence	*Ad hoc* based on RIAS TEIQue-SF	Selective attention, concentration and the ability to socialise were improved by using this active videogame for 40 minutes a day.
Schmidt et al. (2015)	Randomised controlled intervention	181 (126-55)	11.35 (10-12)	PE sessions with team games or aerobic exercise according to experimental group	6 weeks	Executive functions Inhibition	E-Prime Software Flanker Task	The inclusion of cognitive engagement in PA (team games vs. aerobic exercise) leads to greater improvements in cognitive performance.
Tarp et al. (2016)	Cluster-randomised intervention	632 (215-490)	12.9 (12-14)	60 min. moderate school-based PA + 10 min home PA 5 times a week (both)	20 weeks	Cognitive control Academic performance	Eriksen Flanker Task Maths test	There is no PA effect on executive functions and maths performance. The level of PA did not vary, so no causal relationships were established.
Van den Berg et al. (2016)	Randomised controlled intervention	184 (184-NA)	11.7 (10-13)	12-minute aerobic, coordination and strength training by experimental group	2 days (1 control day)	Attention Cognitive performance	d2TA LDST	12-minute aerobic, coordination or strength exercise sessions (mild-to-moderate intensity) have no effect on attention and academic performance.

Note. Concepts. PA: Physical Activity; PE: Physical Education; NA: Not available; GC: Control group; GE: Experimental group. Instruments: BOSST: Behavioral Observation of Students in Schools Tool; CANTAB: Cambridge Neuropsychological Test Automated Battery; CBB: Costage Brief Battery; NYSTP: New York State Testing Program; d2TA: d2 Test of Attention; LDST: Letter Digit Substitution Test; NDET: Norwegian Directorate for Education and Training; RIAS: Reynolds Intellectual Assessment Scales; IGF-M: Test de Inteligencia Factorial; TOL: Tower of London-Drexel task; TMT: Trail-Making Test; TEIQque-SF: Trait and Emotional Intelligence Questionnaire Short Form; SPM: Standard Progressive Matrices; SDQ: Strengths and Difficulties Questionnaire; WIAT-III: Wechsler Individual Achievement Test-Third Edition; WRAT 4: Wide Range Achievement Test.

Current state of the question and discussion

The main conclusions drawn from the systematic review of longitudinal and experimental studies are set out below. The research corpus consisted of 23 scientific papers with randomised designs that address the relationship between doing PA and academic and/or cognitive performance in preadolescents. Various PA prescriptions are used, including active breaks, strength-based training, an aerobics component and multi-component approaches.

Academic performance

Most of the studies that address academic performance using the scores obtained in regular tests show how doing PA results in an improvement in such performance, although this needs to be qualified. In the first place, interventions that involved exercise of greater intensity and length as well as gross motor skills led to more pronounced improvements in academic performance (Beck et al., 2016; Howie et al., 2015; Phillips et al., 2015). This shows the importance of appropriate prescription, as a minimum activation of the body that generates responses which improve cerebral blood supply or endorphin production is required (Krafft et al., 2014).

These findings may also be based on a psycho-pedagogical standpoint. The papers by Mullender-Wijnsma et al. (2015) and Ma et al. (2014) show how the inclusion of tasks that actively work on educational content and the introduction of active breaks improve academic performance in children with lower grades. As underlying reasons for these premises, Quinto and Klausen (2016) demonstrate how the addition of play in academic tasks fosters learning by involving higher levels of intrinsic motivation and less academic stress. Similarly, the inclusion of active breaks makes it possible to restore the attention span and improve cerebral blood supply, leading to cognitive benefits (Krafft et al., 2014). Bunketorp et al. (2015) also report how such programmes promote the perceived wellbeing and behaviour of schoolchildren.

Turning to the fields most closely linked to the advantages of doing PA, the papers by Beck et al. (2016), Fedewa et al. (2015) and Resaland et al. (2016) indicate how the benefits of their intervention programmes were more closely associated with improvements in mathematical performance, with special emphasis on arithmetic, while not finding any relationship with reading comprehension, although Duncan and Johnson (2014) report contradictory findings. The explanation lies in the improvements that doing PA brings about in a number of factors associated with cognitive performance and which are more related to mathematical performance (Donnelly et al., 2017). Finally, no improvements were observed after the guidelines of some studies were applied, although performance did not worsen either. In all of them, the external load involved in terms of length was not high (Bugge et al., 2018; Donnelly et al., 2017; Quinto et al., 2016).

Cognitive performance

Several authors argue that doing PA might not only improve academic performance directly but would also help to enhance cognitive performance, which will have a positive impact on school performance (Donnelly et al., 2017). More specifically, Chen et al. (2017) demonstrate how multi-component training based on strength work, coordination and aerobic capacity enables meta-cognitive development through improvements in attention span and planning which can be explained by better blood supply in the anterior cerebral cortex that results in higher mental activation (Krafft et al., 2014).

The studies analysed indicate the need for PA prescription to meet specific requirements. In particular, Fedewa et al. (2015) did not report any improvement in fluid intelligence when adding 20 minutes of PA per day for 8 months. Similarly, Tarp et al. (2016) and Van den Berg et al. (2016) failed to achieve any changes in executive functions when implementing short-term mild-to-moderate intensity physical exercise programmes. In this respect there are two basic requirements for physical exercise to generate positive changes in cognition. The first is in the load of the intervention performed, involving a minimum of 150 minutes per week of work in which the intensity is moderate (Cheng et al., 2017; Lind et al., 2018). The second requirement lies in the cognitive demands of the task to be performed, since a cooperation sport with an opponent will produce more pronounced cognitive improvements by involving more stimuli, thus helping to improve reasoning ability and selective attention (Ruiz-Ariza et al., 2018; Schmidt et al., 2015).

Physical condition and general health

In addition to the impact of PA on school performance, most of the experimental studies analysed also addressed changes in health status indicator parameters. It was found that regardless of changes in cognitive or academic performance, several components of physical fitness improved in most of the studies, and better levels of cardio-respiratory fitness (Bugge et al., 2018), waist circumference and body mass percentiles (Ardoy et al., 2014; Donnelly et al., 2017) were obtained.

This shows that doing physical activity and sport is an indispensable factor in achieving physical and mental wellbeing from an early age (Mullender-Wijnsma et al., 2015). In fact, Bugge et al. (2018) stress the importance of encouraging an active lifestyle from an early age in order to prevent childhood obesity and several pathologies such as diabetes, cholesterol and cardiovascular problems. Specifically, the World Health Organization (2010) recommends at least 60 minutes of moderate PA a day, a minimum reflected in the load volume in most interventions with positive outcomes.

Study limitations

Finally, the main limitations of this systematic review should be noted. Firstly, the search range should be underlined, as it may be considered both a strength and a limitation. The studies used were confined to the last five years in order to provide an up-to-date picture of the current state of research. However, such a narrow timeframe may have overlooked studies of national and international significance. Another limitation may lie in the selection of only longitudinal and experimental studies. As with the previous limitation, this selection criterion helps to engender relevant conclusions based on results that demonstrate causality. Finally, there is a wide range of instruments for assessing academic and cognitive performance in the studies analysed and this makes it difficult to compare their findings.

Conclusions

Doing PA makes it possible to improve academic performance in preadolescents, yielding higher improvements the greater the volume and intensity of the exercise. The effect of doing PA decreases with time after its discontinuation and the field that benefits most is mathematics and arithmetic.

Cognitive performance also benefits from doing PA. Tasks featuring higher cognitive demands and involving gross motor skills have a greater effect. This makes for improvements in cerebral blood supply, attention and concentration but not in executive functions.

Most of the studies show that regardless of the impact of PA on academic and cognitive performance, improvements are achieved in health status and physical condition, especially through changes in body composition and cardio-respiratory fitness.

Finally, very disparate results are observed in most of the studies, generally due to the existence of a wide diversity of contexts, exercise prescriptions and instruments. Consequently, the criteria for the assessment of the variables analysed need to be standardised.

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