

# EXERCISE SCIENCE IN HIGH SCHOOL BIOLOGY TEXTBOOKS

CIÊNCIA DO EXERCÍCIO EM LIVROS DIDÁTICOS DE BIOLOGIA DO ENSINO MÉDIO

CIENCIA DEL EJERCICIO EN LOS LIBROS DIDÁCTICOS DE BIOLOGÍA DE LA ENSEÑANZA MEDIA

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## ABSTRACT

The content of high school textbooks related to physical activity and exercise is of utmost importance because physical activity and exercise are considered important tools in maintaining and improving health. Our objective was to analyze the presence and quality of exercise science content in high school biology textbooks approved by the National Textbook Plan. A guiding document was developed to enable the analysis of the textbooks. The topics investigated were: I) the extent of content related to exercise science; II) misconceptions about exercise science; III) health benefits attributed to exercise. The academic qualifications of the textbook authors were also analyzed. All analyzed textbooks (n = 9) featured some degree of exercise science content. In addition, ~67% of textbooks analyzed had at least one misconception regarding exercise science, the most common being related to biochemistry and muscle physiology. Also, 93.8% of the authors had undergraduate degrees in biological sciences; 43.8% had doctoral degrees. In conclusion, all high school biology textbooks presented content related to exercise science; however, most of them presented at least one misconception regarding exercise science. Thus, we suggest that the Brazilian National Textbook Plan should improve the criteria for analyzing biology textbooks. **Level of Evidence III; Economic and decision analyses - Development of an economic or decision model.**

**Keywords:** Physical Activity; Physical Exercise; Health Promotion; Hypertension; Health Education.

## RESUMO

O conteúdo dos livros didáticos de ensino médio relacionados à atividade física e ao exercício é de suma importância, uma vez que a atividade física regular e o exercício são considerados como uma importante ferramenta na manutenção e melhoria da saúde. Nosso objetivo foi analisar a presença e a qualidade de conteúdo científico do exercício em livros didáticos de biologia no ensino médio aprovados pelo Plano Nacional de Livros Didáticos. Foi criado um documento orientador para permitir a análise dos livros didáticos. Os tópicos investigados foram: I) a extensão do conteúdo relacionado à ciência do exercício; II) equívocos sobre a ciência do exercício; e III) benefícios à saúde atribuídos ao exercício físico. Também foram analisadas as qualificações acadêmicas dos autores dos livros didáticos. Todos os livros didáticos analisados (n=9) apresentaram algum grau de conteúdo científico de exercício. Além disso, um total de ~67% dos livros didáticos analisados apresentaram pelo menos um equívoco em relação à ciência do exercício, sendo o mais comum relacionado à bioquímica e fisiologia muscular. Além disso, 93,8% dos autores tinham graduação em ciências biológicas; 43,8% tinham doutorado. Em conclusão, todos os livros didáticos de biologia do ensino médio apresentaram conteúdos sobre ciência do exercício; no entanto, a maioria deles apresentou pelo menos um equívoco em relação à ciência do exercício. Assim, sugerimos que o Plano Nacional de Livros Didáticos melhore os critérios de análise dos livros didáticos de biologia. **Nível de Evidência III; Análises econômicas e de decisão - Desenvolvimento de um modelo econômico ou de decisão.**

**Descritores:** Atividade Física; Exercício Físico; Promoção de saúde; Hipertensão; Educação em saúde.

## RESUMEN

El contenido de los libros didácticos de la enseñanza media relacionados con la actividad física y el ejercicio es de suma importancia, ya que la actividad física y el ejercicio regulares se consideran una herramienta importante para el mantenimiento y la mejora de la salud. Nuestro objetivo fue analizar la presencia y la calidad del contenido de ciencias del ejercicio en los libros didácticos de biología de la enseñanza media aprobados por el Plan Nacional de Libros Didácticos de Brasil. Se elaboró un documento guía para permitir el análisis de libros didácticos. Los temas investigados fueron: I) la extensión del contenido relacionado con la ciencia del ejercicio; II) conceptos erróneos sobre la ciencia del ejercicio; y III) los beneficios para la salud atribuidos al ejercicio físico. También se analizaron las calificaciones académicas de los autores de los libros didácticos. Todos los libros didácticos analizados (n = 9) presentan algún grado de contenido de ciencias del ejercicio. Además, un total de ~ 67% de los libros didácticos analizados presentaban al menos un concepto erróneo con respecto a la ciencia del ejercicio, siendo el más común el relacionado con la bioquímica y la fisiología muscular. Además, el 93,8% de los autores tenía una licenciatura en ciencias biológicas

y 43,8% tenía un doctorado. En conclusión, todos los libros didácticos de biología de la escuela secundaria presentaban contenido relacionado con la ciencia del ejercicio; sin embargo, la mayoría de ellos presentaba al menos un concepto erróneo con respecto a la ciencia del ejercicio. Por lo tanto, sugerimos que el Plan Nacional de Libros Didácticos de Brasil mejore los criterios para analizar los libros didácticos de biología. **Nivel de Evidencia III; Análisis económico y de decisión - Desarrollo de modelo económico o de decisión.**

**Descriptor:** Actividad Física; Ejercicio Físico; Promoción de la Salud; Hipertensión; Educación en Salud.

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## INTRODUCTION

Textbooks are important resources for teaching subject and, alongside a blackboard and chalk, represent the only didactic materials available to students and teachers in Brazilian public schools.<sup>1</sup> Further, textbooks can provide pedagogical orientation in an autonomous way, since they may be used as diverse sources to provide teachers with the freedom of choice in selecting the adequate tools needed for the teaching process.<sup>2</sup>

In Brazil, the Ministry of Education has a program that is coordinated by the Basic Education Secretariat, called the Plano Nacional do Livro Didático, or National Textbook Plan (PNLD). In short, PNLD aims to subsidize the pedagogical work of teachers through the distribution of textbooks to students. In addition, PNLD is committed to the quality of the content available within the textbooks. In order to achieve this, the Ministry of Education has designated technical commissions composed by professors and researchers from Brazilian public universities.<sup>3,4</sup> Briefly, the technical commissions evaluate the following criteria: i) respect for legislation, guidelines and general education norms; ii) observance of the ethical principles necessary for building citizenship and republican social life; iii) the coherence and adequacy of the theoretical-methodological approach; iv) the correction and updating of concepts, information and procedures; v) the adequacy and relevance of the guidance provided to the teachers; vi) observance of the orthographic and grammatical rules of the language in which the work has been written; vii) the adequacy of the editorial structure and the graphic design; and viii) the quality of the text and the thematic adequacy.<sup>3,4</sup>

Previous studies have shown the presence of misconceptions within high school<sup>5,6</sup> and university textbooks.<sup>7</sup> In regard to biology textbooks, content analysis has suggested the presence of misconceptions,<sup>8-12</sup> and that quality of images, text-image relationships, and its function for learning is affected.<sup>13-15</sup> Therefore, teachers should be prepared to deal with any inaccuracies such as misconceptions, decontextualized examples, lack of information, and confusing and complex illustrations, as the students that are exposed to these misconceptions may regard them as being factual.<sup>16,17</sup>

In this sense, the approach of the content that is related to physical activity and exercise in high school textbooks is of paramount importance, since regular physical activity and exercise is considered as an important tool for the maintenance and improvement of health and physical fitness.<sup>18,19</sup> Additionally, it is known that regular physical activity and exercise are important factors for the prevention and treatment of several non-communicable diseases such as type 2 diabetes mellitus,<sup>20</sup> arterial hypertension,<sup>21</sup> breast cancer,<sup>22,23</sup> obesity,<sup>24,25</sup> anxiety,<sup>26</sup> and depression.<sup>27,28</sup> Thus, it is important that students are aware of accurate information.

Therefore, biology textbooks play an important position as they are a fundamental pedagogical tool that is capable of assisting teaching practices and provides students with scientific and updated information regarding health within the biological field. Given that it is essential that textbooks present high-quality content (e.g., updated scientific knowledge), this study aims to analyze the presence and quality of

exercise science content in high school biology textbooks approved by the PNLD. We hypothesized that the biology textbooks would present misconceptions regarding exercise science.

## METHODS

### Book selection

We analyzed all biology textbooks (n = 9)<sup>29-37</sup> that were approved by PNLD and available to Brazilian public high schools in 2015 (Table 1).

### Content analysis

A guiding document was created to allow the analysis of each biology textbook to be organized into a schematic model. This guide was adapted from de Lira et al.<sup>7</sup> and the topics addressed in this guiding document were: i) Presence of content that is related to exercise science; ii) presence of misconceptions regarding exercise science; and iii) health benefits provided by physical exercise. All textbooks were carefully investigated in order to locate the text, chapters, or references that addressed the topic of exercise science. After the material was located, a deep content analysis was performed by two researchers (S.P.M. and C.A.B.L.). One of the researchers (S.P.M.) is a high school teacher, and the other (C.A.B.L.) is an exercise physiology professor at the Faculty of Physical Education and Dance at the Federal University of Goiás (Brazil). To this end, exercise science contents present in the biology textbook were transcribed and researchers (S.P.M. and C.A.B.L.) analyzed difference from the contents of state of the art references and highlighted the incorrect information identified in the textbooks.

### About the authors and colleagues

Additionally, the academic qualifications of the textbooks' authors and colleagues were analyzed. The study investigated the: i) Academic education (undergraduate, master's and doctorate levels), and ii) their areas of expertise. This information was extracted from the Lattes platform, a Brazilian database for researcher's Curriculum Vitae, that was created and managed by the National Council for Scientific and Technological Development Brazil (Conselho Nacional de Desenvolvimento Científico e Tecnológico, CNPq), and also through the information presented in the analyzed textbooks.

**Table 1.** Biology textbooks selected by the Brazilian National Textbook Plan.

Authors	Title	Edition	Publisher	Years
Lopes and Rosso <sup>29</sup>	Bio	2 <sup>nd</sup>	Saraiva	2013
Mendonça <sup>30</sup>	Biologia	2 <sup>nd</sup>	AJS	2013
Silva Junior, Sasson and Caldini Junior <sup>31</sup>	Biologia	11 <sup>st</sup>	Saraiva	2013
Amabis and Martho <sup>32</sup>	Biologia em Contexto	1 <sup>st</sup>	Moderna	2013
Linhares and Gewandsznajder <sup>33</sup>	Biologia Hoje	2 <sup>nd</sup>	Ática	2013
Favaretto <sup>34</sup>	Biologia: Unidade and Diversidade	1 <sup>st</sup>	Saraiva	2013
Bröckelmann <sup>35</sup>	Conexões com a Biologia	1 <sup>st</sup>	Moderna	2013
Bizzo <sup>36</sup>	Novas Bases da Biologia	2 <sup>nd</sup>	Ática	2013
Takeuchi and Osorio <sup>37</sup>	Ser protagonista - Biologia	2 <sup>nd</sup>	SM	2013

## Statistical analysis

A descriptive statistical analysis was performed (mean, standard deviation, and absolute and relative frequencies) using Excel software (version 2016, USA).

## RESULTS

### About the authors and colleagues

Of the 32 authors and colleagues present in the analyzed textbooks, 30 (93.8%) held an undergraduate degree in biological sciences, while one held a degree in medicine, and one in pedagogy; 14 authors (43.8%) had Ph.D. degrees; four (12.6%) had master's degrees; two (6.3%) were master's degree candidates; one (3.1%) had only an undergraduate degree; and 11 of the authors and colleagues (34.4%) did not have any academic information available in the textbooks and/or on the Lattes platform. Among the authors and colleagues that held graduate degrees (master's or Ph.D. degrees,  $n=18$ ), six had expertise in zoology; three in genetics; three in education science; one in experimental physiopathology; one in ecology; one in general physiology; one in biotechnology; one in biochemistry; and one whose area of expertise could not be located.

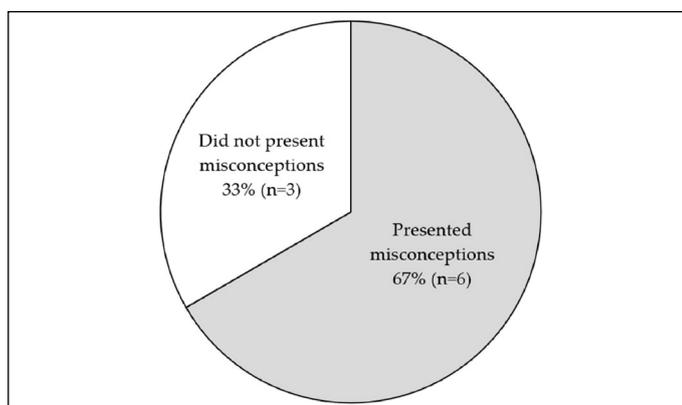
### Exercise science content

All analyzed textbooks presented some exercise science content, although each collection used different approaches. The most commonly found content regarded: I) Doping and the use of anabolic steroids; II) exercise biochemistry; III) the benefits of physical exercise to health, and IV) exercise at high altitude. A total of ~67% of the analyzed textbooks presented at least one misconception regarding exercise science (Figure 1). Also, a total of 10 exercise science misconceptions were found across the analyzed biology textbooks, with the most common being related to biochemistry and muscular physiology (Figure 2) Table 2 presents a qualitative analysis of each textbook that was included in the study.

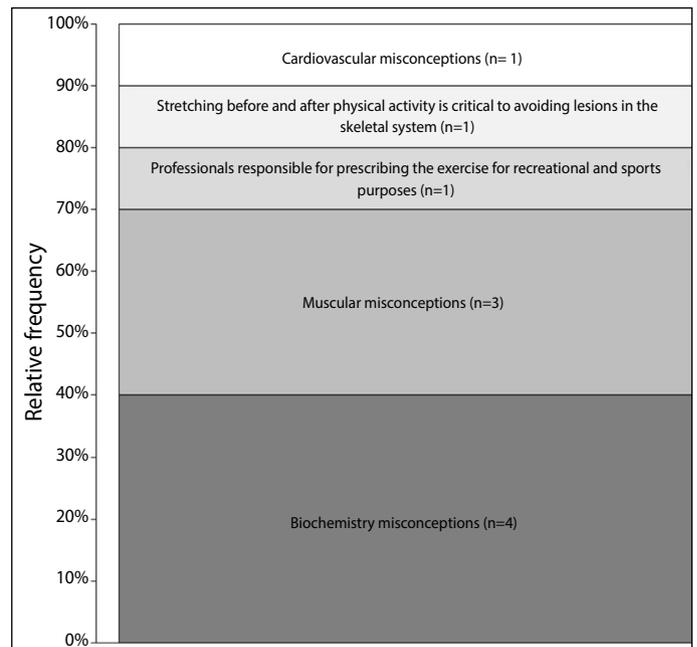
## DISCUSSION

This study aimed to analyze the presence and quality of the exercise science content in high school biology textbooks as approved by the PNLD. Our main finding was that most of high school biology textbooks (~67%) analyzed presented at least one misconception regarding exercise science. We found that all analyzed textbooks addressed at least one topic that was related to exercise science such as doping, the use of anabolic androgenic steroids, exercise biochemistry, the health benefits of exercise practice, and exercise at high altitudes.

There is much evidence to suggest that the use of anabolic androgenic steroids is unsafe<sup>38-40</sup> and can produce several health issues and even death.<sup>41</sup> We consider the presence of this content in high school



**Figure 1.** Presence of exercise science misconceptions among the high school biology textbook analyzed.



**Figure 2.** Relative frequency of the exercise science misconceptions.

textbooks is vital in raising awareness and sensitizing adolescents to the deleterious effects of anabolic androgenic steroids. In regard to exercise biochemistry, some of the analyzed textbooks mentioned that lactate is produced only during exercise.<sup>30,33</sup> However, this is untrue, since lactate is also produced during rest conditions.<sup>42</sup>

Although the implementation of PNLD has attempted to improve the quality of textbooks, it is still possible to identify misconceptions and incomplete information within these textbooks. Misconceptions within biology textbooks are common and are not only restricted to the topics that are related to physiology.<sup>6,10,12</sup> Previous studies found misconceptions in the content that was related to leishmaniasis,<sup>6</sup> the dengue virus,<sup>12</sup> and venomous snakes accidents.<sup>10</sup> Therefore, although PNLD carefully evaluates high school textbooks, teachers should also be able to analyze and evaluate the contents of the textbooks that are used in biology classes in order to link the content to the students' daily lives. However, it is reasonable to assume that teachers with poor academic backgrounds may not be able to identify recurring misconceptions within the textbooks. Therefore, to improve knowledge and provide updates on recent scientific advances in the field, continuing education programs are need.

A possible explanation for the misconceptions found could be due to most of the analyzed textbooks being written by one to three authors. As biology is a discipline that has traditionally been organized by various life sciences (cytology, genetics, evolution, ecology, zoology, botany, and physiology); therefore, it is reasonable to assume that it is difficult for a limited number of authors to provide specific information on all of these topics. This situation is potentially aggravated once major scientific advances have been made within the biological fields to include the sub-topic of human and exercise physiology.<sup>43,44</sup> These advances would generate substantial volumes of new information and more complex knowledge which makes it difficult for teachers to remain updated with.<sup>45,46</sup>

The qualifications of the master's and/or doctorate students is another aspect to be considered. It is well known that a teacher that participates in graduate programs may have a better academic background which would enable them to remain updated.<sup>47</sup> In the present study, only 18 of the 32 authors and colleagues had a master's and/or Ph.D. degree. Additionally, only 21 of the 32 authors and colleagues had

**Table 2.** Qualitative analysis of each textbook included in the study.

Authors	Comments
Lopes and Rosso <sup>29</sup>	<ul style="list-style-type: none"> <li>It was reported that the heart starts to pump more blood in trained individuals. However, this statement is dubious. The maximum cardiac output of a trained individual is higher when compared to the maximum cardiac output of a sedentary individual. The resting and submaximal cardiac output (same absolute intensity of exercise) of sedentary and trained individuals is the same, while the systolic volume changes (decreases) and the heart rate (increases). However, in the same text, it was correctly pointed out that the increase of exercise intensity should be gradual as is recommended by the principle of progressive overload. Moreover, it was correctly reported that physical exercise should be guided by a trained professional, otherwise physical exercise may be harmful rather than beneficial.</li> </ul>
Mendonça <sup>30</sup>	<ul style="list-style-type: none"> <li>It was reported that "During intense physical activity, some groups of muscle cells begin to perform lactic fermentation," implying that it is only during intense physical activity that the muscle cells provide lactic fermentation (anaerobic glycolysis). However, this is a misleading concept, since lactic fermentation occurs from rest (~1 mMol/L) to maximum exercise.</li> <li>It was reported that "The accumulation of lactic acid in muscle tissue is one of the factors that causes muscle fatigue." However, the accumulation of hydrogen ions is responsible for fatigue, rather than lactic acid in muscle tissue. Furthermore, biochemically, lactic acid does not exist, what is produced by muscle fiber is lactate.</li> <li>It was reported that in order to maximize the benefits of physical activity, it is crucial to seek guidance from a physical education and physical therapy professional. However, in Brazil, the only professional that is legally qualified to prescribe physical exercise for recreational and sports purposes is the physical education professional.</li> <li>It was reported that "Stretching before and after physical activity is critical to avoiding lesions in the skeletal system." However, it is important to note that there is no scientific consensus to date to confirm the author's claim.</li> </ul>
Silva Junior, Sasson and Caldini Junior <sup>31</sup>	<ul style="list-style-type: none"> <li>The textbook only presents a supplementary text to address the use of anabolic steroids.</li> </ul>
Amabis and Martho <sup>32</sup>	<ul style="list-style-type: none"> <li>In the text that addresses muscles and physical exercises, the authors confused fast twitch fibers with slow twitch fibers.</li> </ul>
Linhares and Gewandznajder <sup>33</sup>	<ul style="list-style-type: none"> <li>It was reported that lactic acid is only produced during exercise. First, lactic acid does not exist, what is produced by muscle fiber is lactate. Furthermore, although in low concentration, lactate is also produced at rest.</li> <li>The phosphagen system was not reported to be predominantly used during extremely high intensity exercises with very short durations. In addition, the transfer of the phosphate group to ADP, catalyzed by the enzyme creatine kinase, was not mentioned.</li> </ul>
Favaretto <sup>34</sup>	<ul style="list-style-type: none"> <li>In a text that stated "Physical exercise attenuates symptoms of Parkinson and Alzheimer disease," the author presented interesting information regarding the benefits of regular physical activity in patients with these diseases.</li> </ul>
Bröckelmann <sup>35</sup>	<ul style="list-style-type: none"> <li>Regarding physical exercise and doping, the author addressed different substances that favor the athlete, such as erythropoietin, beta blockers, diuretics, and others.</li> </ul>
Bizzo <sup>36</sup>	<ul style="list-style-type: none"> <li>It was reported that "Prolonged muscle activity in an intense and long exercise may be accompanied by soreness in the following days, especially when too much effort is performed without prior preparation," suggesting that soreness can only occur after intense and long exercise periods. However, muscle soreness is known to occur as a result of uncommon intense effort and is not necessarily related to the duration of the activity.</li> </ul>
Takeuchi and Osorio <sup>37</sup>	<ul style="list-style-type: none"> <li>It was reported that "The increase in skeletal muscle related to physical exercise is due not to increasing the number of muscle cells, but mainly to the formation of new myofibers." However, there is scientific evidence that states that muscle hypertrophy can occur due to the formation of new cells.</li> </ul>

a Curriculum Vitae registered in the Lattes database, and it is noteworthy that some of these were outdated. This result is worrying because it denotes that the authors of the textbooks are not updating their knowledge. Therefore, this might be another possible explanation for the presence of the misconceptions regarding exercise science found in the analyzed biology textbooks.

One of the possible consequences of these misconceptions is the fact that students may potentially bring these misconceptions into their personal and professional lives.<sup>17</sup> In regard to their personal lives, students may make misleading judgments regarding the biological phenomena that they may experience throughout their lives.<sup>48,49</sup> Within their professional lives, misconceptions may be more evident if the student pursues a career within the biological sciences.<sup>17</sup> In addition, it is reasonable to assume that the misconceptions may also disrupt a student's entry into university since they are required to complete several academic exams. However, for the students that enter universities (especially undergraduate health courses), it is possible to remove such misconceptions.

Unfortunately, even within universities, several previous studies<sup>50-53</sup> have shown that undergraduate health students present misconceptions about disciplines such as physiology and biochemistry. It is possible that such misconceptions, along with other motives, may stem from textbook contents, which consequently may affect these future health professionals. Leal et al.<sup>17</sup> showed that physical education professionals, physiotherapists, and nutritionists presented important misconceptions regarding the disciplines that are related to exercise physiology. Further, other studies have demonstrated the presence of misconceptions in health professionals regarding epilepsy,<sup>54,55</sup> poliomyelitis, and post-poliomyelitis syndromes.<sup>56</sup>

Recently, de Lira et al.<sup>57</sup> showed that most of the undergraduate programs in health science analyzed, except for physical education, did not present the coursework of exercise physiology (or a similar coursework) in their curricular structures. Therefore, this scenario can be the cause of misconceptions presented by students and health professionals.

Promoting health education among adolescents is an important mechanism for the dissemination of valid knowledge to prevent diseases and improve hygiene.<sup>58</sup> Moreover, adolescents become important health agents when divulging to their families what they learned at school.<sup>59</sup>

According to the 2018 school census conducted by the Brazilian Ministry of Education, there are approximately 48.5 million students; of which 7.7 million are enrolled in high school.<sup>60</sup> Considering that all these high school students use textbooks to learn, it is estimated that there are approximately 7.7 million potential "education agents" disseminating the correct or incorrect contents of these textbooks. Therefore, it is important to withdraw the misconceptions from the analyzed biology textbooks and use this opportunity to introduce the correct and adequate content in regard to exercise science.

### Strengths and limitations of the study

Our study is not without limitations. One consideration is that a textbook that contains little content and superficial explanations including misconceptions is inferior when compared to that of a textbook with a more in-depth approach. Therefore, the textbooks that contained few misconceptions are not necessarily regarded as the best. Ruppenthal & Schetinger<sup>1</sup> evaluated this aspect by using the percentage of a given topic in relation to the total number of pages in the textbook. Although

this method was interesting and objective, we do not consider such methods to be an adequate strategy since this analysis was influenced by the font and page size. Similarly, as with any qualitative analysis, it is subjective, and subject to different interpretations. Our study did not aim to classify the textbooks but rather to indicate the aspects that required the attention of the teacher when using the analyzed textbooks as a resource within the classroom. Finally, our results might help the authors of the analyzed textbooks to improve the future editions. Future studies should assess the depth of the investigated content. Furthermore, it is desirable that the books are evaluated by specialists in each subject.

## CONCLUSIONS

All the high school biology textbooks analyzed presented content regarding exercise science; however, most of them presented at least one misconception regarding exercise science. Therefore, we suggest that PNL

improves the criteria for analyzing high school biology textbooks. Also, it is important that teachers continually develop their skills in analyzing didactic collections, since they are plausible of errors even after the analysis from educational authorities. Further, future studies on the analysis of other physiological content within biology textbooks is desirable.

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