

Article

Perceived Barrier Profiles Associated with Insufficient Physical Activity Among University Students: A Multicountry Decision-Tree Study

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Abstract

Insufficient physical activity (IPA) among university students remains an important public health concern associated with adverse health outcomes. Although barriers to physical activity (PA) are widely documented, less is known about how these barriers cluster within different university contexts and student subgroups. This study examined hierarchical configurations of perceived barriers associated with IPA in a multicountry university sample. A cross-sectional analytical study was conducted with 686 undergraduate students (60.8% women; mean age = 22.4 ± 5.1 years) from Chile, Mexico, Spain, and Italy. Perceived barriers were assessed using the BBAQ-21 and self-reported PA using the IPAQ–Short Form. CART and Exhaustive CHAID decision-tree models were applied to identify subgroup configurations based on cumulative barrier burden. Country-based subsamples and self-reported post-pandemic PA emerged as the principal segmentation variables. The Mexican subsample showed the highest barrier burden. Students reporting increased PA generally clustered within lower-barrier configurations, whereas stable or reduced PA tended to coincide with greater perceived barrier burden. Perceived barriers formed differentiated and context-dependent configurations associated with PA patterns. These findings provide exploratory insight into how barriers cluster within university populations and support more context-aware interpretation of PA-related constraints within higher education settings.

Keywords: physical activity; health-promoting universities; young adults; behavioural segmentation; socioecological model; CART and CHAID analysis



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1. Introduction

Insufficient PA (IPA) is widely recognised as a major modifiable risk factor for non-communicable diseases, with documented physical, psychological, and metabolic consequences (Bull et al., 2020; World Health Organization, 2018). Although physical inactivity has often received less public attention than other health-risk behaviours, growing evidence situates it among the most relevant behavioural concerns during youth and emerging adulthood, when lifestyle habits become increasingly established and may persist across the life course (Aceijas et al., 2017; Edelmann et al., 2022). Across many countries, a substantial proportion of young adults do not achieve recommended physical activity (PA) levels, particularly during periods of educational and social transition (Aceijas et al., 2017; Edelmann et al., 2022).

The transition to university represents one of these critical periods. Entry into higher education often coincides with changing routines, increased autonomy, and new social and academic demands that may alter established health behaviours (Aceijas et al., 2017; Castro et al., 2018). Time pressures, shifting priorities, and adaptation to unfamiliar environments can make regular PA more difficult to sustain and may contribute to more sedentary lifestyles (Castro et al., 2018; Edelmann et al., 2022). For this reason, university students constitute a particularly relevant population for examining how PA behaviours are shaped and negotiated within changing contexts.

Among the factors associated with PA engagement in this population, perceived barriers have emerged consistently as a central concern. Students commonly report lack of time, academic workload, fatigue, limited motivation, and restricted access to facilities as obstacles to regular participation (Blanco et al., 2019; Espada et al., 2023; Griffiths et al., 2022; Martínez-Lemos et al., 2014; Sevil et al., 2017). These barriers, however, are not simply individual difficulties or isolated motivational shortcomings. Increasingly, they are understood as experiences embedded within broader psychological, social, and environmental conditions, including institutional arrangements, social expectations, and access to resources (Amornsriwatanakul et al., 2023; Murphy et al., 2024; Zhang et al., 2022). From this perspective, perceived barriers may provide insight into how personal circumstances and contextual conditions intersect in ways that hinder or facilitate engagement in PA (Brown et al., 2024; Sallis et al., 2008).

This interpretation aligns with socioecological perspectives on health behaviour, which conceptualise PA as the product of interacting influences operating across multiple levels rather than as the outcome of isolated individual choices (Sallis et al., 2008). Ecological models emphasise that intrapersonal characteristics, interpersonal relationships, organisational environments, community settings, and policy conditions influence behaviour in interconnected and context-sensitive ways (Sallis et al., 2008). Within this framework, active lifestyles are more likely to emerge when individual motivation and behavioural capacities are supported by favourable social norms, accessible environments, and institutional conditions that make healthy choices realistic and sustainable.

A related perspective is offered by the Health-Promoting Universities (HPU) framework and the principles articulated in the Okanagan Charter, which position universities not merely as educational institutions but as environments capable of embedding health and wellbeing into organisational culture, policies, services, and academic life (Okanagan Charter, 2015; Sánchez-Ordóñez & Gimeno-Navarro, 2025). From this whole-system perspective, universities are expected to foster supportive environments, promote wellbeing and equity, and contribute actively to health promotion within and beyond campus communities (Okanagan Charter, 2015). Viewed through these complementary lenses, barriers to PA are understood less as personal deficits and more as context-sensitive experiences arising through interaction between individuals and the environments in which they study and live.

Recent evidence suggests that barriers to PA among university students are neither experienced nor organised uniformly. Systematic reviews have identified recurring domains—particularly those related to time constraints, motivation, environmental conditions, and social support—indicating that broad categories of barriers appear consistently across university populations (Ferreira et al., 2022). Yet the recurrence of these domains should not be interpreted as evidence of contextual uniformity. Rather, barriers that share similar labels may differ substantially in their intensity, perceived relevance, and interaction with everyday circumstances (Brown et al., 2024). In practice, students may encounter comparable challenges but experience and prioritise them differently depending on their social environments, institutional contexts, and available resources.

This variability is increasingly reflected in empirical studies showing that PA-related influences interact differently across sociodemographic and contextual conditions (Amorn-sriwatanakul et al., 2023; Zhang et al., 2022). Research involving university populations from both European and Latin American contexts has repeatedly identified time-related constraints and motivational factors among the most commonly reported barriers (Ilić et al., 2022; Martínez-Lemos et al., 2014; Sevil et al., 2017; Sukys et al., 2019). Even so, similar barrier domains do not necessarily combine in the same ways across groups or settings. This distinction is important, as uniform assumptions about student populations may obscure meaningful heterogeneity and limit understanding of how barriers cluster within particular contexts.

Despite the growing literature on PA barriers among university students, most studies have focused on isolated determinants or linear associations. Less attention has been paid to how multiple barriers interact simultaneously and form differentiated subgroup configurations. Analytical approaches capable of identifying nonlinear and hierarchical relationships may therefore offer added value, particularly when the objective is to explore subgroup heterogeneity rather than estimate independent causal effects.

Decision-tree approaches such as Classification and Regression Trees (CART) and Chi-square Automatic Interaction Detection (CHAID) provide one such alternative (Breiman et al., 1984; Kass, 1980; Lemon et al., 2003). Rather than assuming linearity or uniform effects across populations, these methods allow exploration of hierarchical structures and interactions that may remain hidden in conventional modelling strategies. Within the present study, CART and CHAID were employed as complementary and segmentation-oriented techniques intended to characterise subgroup configurations and examine whether similar contextual patterns emerged across analytical approaches.

Interpretation of contextual variation in multicountry university samples also requires caution. Differences observed across country-based subsamples may reflect not only broader sociocultural environments but also institutional characteristics, disciplinary composition, and recruitment contexts. National subsamples are therefore unlikely to represent purely national or cultural effects. In the present study, country was conceptualised primarily as a contextual indicator encompassing intertwined institutional, academic, and sociocultural conditions rather than as an independent explanatory determinant.

Against this background, the present study sought to identify hierarchical profiles of perceived barriers associated with IPA among university students from four countries and to examine whether complementary decision-tree approaches (CART and Exhaustive CHAID) converged in detecting context-sensitive subgroup configurations. Rather than identifying direct profiles of physical inactivity, the study aimed to characterise how perceived barriers and contextual factors cluster within university populations and relate to differing patterns of IPA. From a context-informed health promotion perspective, understanding these configurations may contribute to subgroup characterisation and generate exploratory hypotheses regarding how clustered barriers relate to PA engagement during a critical stage of life.

2. Materials and Methods

2.1. Study Design and Participants

A cross-sectional analytical study was conducted to explore hierarchical configurations of perceived barriers associated with IPA among university students using decision-tree segmentation approaches. Rather than estimating independent causal effects, this design sought to examine how behavioural, sociodemographic, and contextual variables clustered within differentiated subgroup profiles.

Participants were recruited through collaborating universities in Chile, Mexico, Spain, and Italy using institution-based convenience sampling. Recruitment reflected the academic programmes accessible to each participating research team and did not aim to establish strict equivalence of disciplines across countries. Consequently, disciplinary composition differed across national subsamples and reflected the institutional and organisational characteristics of each participating university context.

Eligibility criteria included: (i) enrolment as an undergraduate student, (ii) age ≥ 18 years, and (iii) provision of informed consent.

A total of 808 questionnaires were received and screened prior to analysis. Cases with substantial missing information in key variables required for derivation of study outcomes (e.g., BBAQ-21, IPAQ-SF, or self-reported anthropometric data) were excluded. Responses were also removed when evidence of inconsistency compromised interpretability, including duplicate submissions identified through timestamp and IP verification or logically incompatible information across key variables.

Following screening, 122 cases were excluded and the final analytical sample comprised 686 valid questionnaires (417 women, 60.8%; mean age = 22.4 years, SD = 5.1): Chile ($n = 161$, 23.5%), Mexico ($n = 162$, 23.6%), Spain ($n = 180$, 26.2%), and Italy ($n = 183$, 26.7%).

The study followed STROBE recommendations for reporting cross-sectional research (von Elm et al., 2007).

2.2. Instruments and Measures

Data were collected using a structured self-administered online questionnaire (Google Forms). The instrument was originally developed in Spanish and adapted for cross-cultural implementation using forward-backward translation procedures combined with expert review by local research teams. This process aimed to support semantic, conceptual, and contextual equivalence across participating countries. Formal measurement invariance testing was not conducted; therefore, strict psychometric equivalence across settings cannot be assumed.

Sociodemographic and academic variables included sex, age, country, academic programme, year of study, cohabitation status, employment, financial independence, and perceived socioeconomic status.

Country was incorporated as a contextual segmentation variable rather than as a direct proxy for national culture. Given differences in institutional settings, academic composition, and recruitment contexts across participating universities, country was interpreted as a composite indicator encompassing overlapping sociocultural, academic, and environmental conditions.

Health-related variables included self-reported height and weight, used to calculate body mass index (BMI; kg/m^2) according to World Health Organization (WHO) criteria (WHO, 1995). Participants also reported current medical or psychological treatment, adherence to medically prescribed diets, previous COVID-19 infection, and restrictions to PA during lockdown periods.

Participants additionally reported perceived changes in PA relative to the pandemic period. This variable was interpreted as a self-perceived behavioural trajectory indicator rather than as an objective longitudinal measure of behavioural change.

Habitual physical activity was assessed using the International Physical Activity Questionnaire–Short Form (IPAQ-SF). The instrument captures self-reported frequency and duration of walking and moderate- and vigorous-intensity PA during the previous seven days. Weekly activity was expressed as MET-min/week following standardised scoring procedures and categorised as low, moderate, or high according to established guidelines (Bull et al., 2020; Craig et al., 2003).

The IPAQ-SF has demonstrated acceptable reliability and modest criterion validity across diverse populations, including university students and young adults (Craig et al., 2003; Dinger et al., 2006). Although self-reported measures may overestimate PA levels relative to objective assessments, the IPAQ-SF remains widely used for epidemiological categorisation and population-based surveillance (Lee et al., 2011). In the present study, IPAQ-derived indicators were interpreted as self-reported behavioural measures suitable for epidemiological profiling and exploratory subgroup segmentation rather than as objective estimates of PA volume or energy expenditure.

IPAQ-SF data were processed following the official IPAQ Data Processing and Analysis Guidelines (IPAQ Research Committee, 2005). Duration values exceeding recommended limits were truncated according to guideline criteria, logical inconsistencies between frequency and duration were checked, and total PA (MET-min/week) was calculated using standard MET coefficients for walking and moderate- and vigorous-intensity PA. Participants were subsequently classified into low, moderate, and high PA categories using standard IPAQ scoring procedures.

Perceived barriers to PA were assessed using the Barriers to Being Active Questionnaire (BBAQ-21) (U.S. Department of Health and Human Services et al., 1999). The instrument comprises seven domains represented by three items each and scored on a four-point Likert scale (0–3). Domain scores range from 0 to 9, with scores ≥ 5 interpreted as indicating the presence of a meaningful perceived barrier according to the original scoring framework (U.S. Department of Health and Human Services et al., 1999).

The BBAQ-21 has shown acceptable psychometric performance in university populations, including evidence of internal consistency (Cronbach's $\alpha \approx 0.81$ – 0.84), test–retest reliability (ICC = 0.46–0.87), and factorial validity in undergraduate samples (Rubio-Henao et al., 2015). More recent cross-cultural adaptations have further supported its use as a multidimensional measure of barriers to PA (Blanco-Martínez et al., 2025).

The ≥ 5 threshold was applied consistently across participating countries to facilitate comparative and exploratory profiling. This cut-point derives from the original BBAQ framework and has not been specifically recalibrated for university populations in Chile, Mexico, Spain, or Italy. Accordingly, barrier classifications should be interpreted as comparative and segmentation-oriented indicators rather than culturally invariant or diagnostic thresholds.

For descriptive analyses, prevalence of each barrier domain and cumulative barrier burden—defined as the number of domains scoring ≥ 5 —were calculated. Given the segmentation-oriented aims of the study, individual domains were additionally aggregated into a cumulative burden indicator intended to capture the multidimensional character of perceived barriers while facilitating parsimonious decision-tree modelling.

Two outcome specifications were used for hierarchical analyses. For CART, a binary outcome distinguished lower burden (0–2 domains ≥ 5) from higher burden (≥ 3 domains ≥ 5). For CHAID, a multinomial specification was employed (low: 0–1; moderate: 2–3; high: ≥ 4 domains ≥ 5), allowing exploration of broader subgroup differentiation.

The analytical focus was not latent construct modelling or instrument validation but identification of hierarchical subgroup configurations using domain-level threshold criteria consistent with the original BBAQ scoring framework. Because the instrument was implemented across different cultural and institutional settings without formal measurement invariance testing, cross-country comparisons should be interpreted cautiously and viewed as exploratory and context-sensitive.

2.3. Procedures

Data collection took place between November 2023 and April 2024 using non-probability convenience sampling. Questionnaires were distributed through institutional channels, including email lists, learning management systems, and classroom announcements. Teaching staff provided standardised participation instructions across participating universities.

Participation was voluntary and uncompensated. Average completion time was approximately 12 min. Responses were anonymous and securely stored. Duplicate entries were screened using timestamp and IP verification procedures. Initial screening excluded cases with substantial missing or inconsistent information affecting key study variables. Following this process, residual missing data within the final analytical sample were minimal (<2%) and were handled using pairwise deletion where applicable.

Although participating countries followed comparable procedures during the same general period, seasonal and contextual conditions were not formally controlled and may have influenced physical activity patterns and perceived barriers.

2.4. Ethical Considerations

All procedures complied with the ethical principles of the Declaration of Helsinki (World Medical Association, 2013). Ethical approval was granted by the Ethics Committee of the Universidad Autónoma del Estado de México (ICAR code 01-SEP-2023). Participants received information regarding study aims and procedures and provided electronic informed consent before participation.

2.5. Statistical Analysis

All analyses were conducted using IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA). Statistical significance was established at $p < 0.05$ (two-tailed).

Descriptive analyses are presented as means and standard deviations for continuous variables and frequencies and percentages for categorical variables. Group differences were examined using chi-square tests, with effect sizes reported as Cramer's V. Adjusted standardised residuals ($|ASR| \geq 1.96$) were inspected to identify cells contributing to significant associations.

To further examine whether observed variation in PA levels reflected disciplinary composition and related contextual factors, a complementary ordinal logistic regression analysis was conducted with PA level (low, moderate, high) as the dependent variable. Country, academic programme, gender, BMI, socioeconomic status, employment, treatment status, and post-pandemic PA trajectory were entered as categorical predictors. Model adequacy was evaluated using likelihood-ratio statistics, Pearson and deviance goodness-of-fit indices, pseudo- R^2 estimates, and the proportional-odds assumption (test of parallel lines). This complementary analysis was intended to support interpretation of contextual findings rather than establish causal or predictive relationships.

Hierarchical segmentation analyses were conducted using Classification and Regression Trees (CART) and Exhaustive Chi-square Automatic Interaction Detection (CHAID) algorithms (Breiman et al., 1984; Kass, 1980; Lemon et al., 2003). These approaches were selected to explore subgroup differentiation and hierarchical interactions among behavioural, sociodemographic, health-related, and contextual variables associated with perceived barrier burden.

The combined use of CART and Exhaustive CHAID was intentional and methodologically complementary. CART was employed to optimise binary subgroup classification and identify parsimonious hierarchical structures, whereas CHAID allowed examination of multinomial differentiation and broader segmentation patterns. Convergence between both

approaches was interpreted as supporting stability and interpretability of the identified subgroup configurations.

Predictor variables included sociodemographic characteristics, health-related indicators, IPAQ-derived PA level, self-perceived post-pandemic behavioural trajectory, and contextual variables related to pandemic experiences. Variable selection was informed by socioecological perspectives (Sallis et al., 2008) and the Health-Promoting Universities framework (Sánchez-Ordóñez & Gimeno-Navarro, 2025), prioritising determinants theoretically relevant to variability in barrier burden.

CART models were estimated using the Gini impurity criterion, with a maximum depth of five levels, minimum parent node size of 60 cases, and minimum child node size of 30 cases. To reduce overfitting and improve subgroup stability, cost-complexity pruning and 10-fold cross-validation were applied.

Exhaustive CHAID models were estimated with a maximum depth of three levels using Bonferroni-adjusted chi-square tests and identical node-size criteria. Cross-validation procedures were likewise implemented.

Different outcome specifications were selected to align with the analytical properties of each algorithm. Binary classification was applied in CART to support classification stability, whereas CHAID employed multinomial categories to take advantage of its multiway segmentation capacity (Breiman et al., 1984; Kass, 1980). This dual operationalisation provided complementary perspectives on barrier burden while maintaining coherence in hierarchical interpretation.

Decision-tree outputs were interpreted as empirically derived subgroup configurations associated with differing levels of perceived barrier burden in relation to PA-related indicators.

3. Results

3.1. Sample Characteristics

Table 1 presents the sociodemographic and health-related characteristics of the 686 university students included in the study from Chile ($n = 161$), Spain ($n = 180$), Italy ($n = 183$), and Mexico ($n = 162$).

Table 1. Sociodemographic, academic, health, and behavioural characteristics of the sample by country, including adjusted residuals for chi-square comparisons.

		Total ($n = 686$)	Chile ($n = 161$)	Spain ($n = 180$)	Italy ($n = 183$)	Mexico ($n = 162$)
		f_i (%)	f_i (%) [R]	f_i (%) [R]	f_i (%) [R]	f_i (%) [R]
Gender ***	Female	417 (60.8)	57 (35.4) [−7.5]	109 (60.6) [−0.1]	134 (73.2) [4.0]	117 (72.2) [3.4]
	Male	269 (39.2)	104 (64.6) [7.5]	71 (39.4) [0.1]	49 (26.8) [−4.0]	45 (27.8) [−3.4]
Study ***	Pedagogy	129 (18.8)	0 (0.0) [−7.0]	27 (15.0) [−1.5]	1 (0.5) [−7.4]	101 (62.3) [16.2]
	Early Childhood Education	15 (2.2)	0 (0.0) [−2.2]	15 (8.3) [6.6]	0 (0.0) [−2.4]	0 (0.0) [−2.2]
	Primary Education	130 (19.0)	0 (0.0) [−7.0]	130 (72.2) [21.2]	0 (0.0) [−7.6]	0 (0.0) [−7.0]
	Physical Education Pedagogy	161 (23.5)	161 (100) [26.2]	0 (0.0) [−8.7]	0 (0.0) [−8.7]	0 (0.0) [−8.1]
	Clinical Psychology	67 (9.8)	0 (0.0) [−4.8]	0 (0.0) [−5.1]	67 (36.6) [14.3]	0 (0.0) [−4.8]
	Educational Psychology	88 (12.8)	0 (0.0) [−5.6]	0 (0.0) [−6.0]	74 (40.4) [13.0]	14 (8.6) [−1.8]
	Educational Therapy	47 (6.9)	0 (0.0) [−3.9]	0 (0.0) [−4.2]	0 (0.0) [−4.3]	47 (29.0) [12.8]
	Social and Vocational Pedagogies and Others	49 (7.1)	0 (0.0) [−4.0]	8 (4.4) [−1.6]	41 (22.4) [9.4]	0 (0.0) [−4.0]
Year ***	First	245 (35.7)	75 (46.6) [3.3]	62 (34.4) [−0.4]	36 (19.7) [−5.3]	72 (44.4) [2.7]
	Second	94 (13.7)	4 (2.5) [−4.7]	59 (32.8) [8.7]	16 (8.7) [−2.3]	15 (9.3) [−1.9]
	Third	115 (16.8)	22 (13.7) [−1.2]	22 (12.2) [−1.9]	16 (8.7) [−3.4]	55 (34.0) [6.7]
	Fourth	105 (15.3)	8 (5.0) [−4.2]	37 (20.6) [2.3]	52 (28.4) [5.8]	8 (4.9) [−4.2]
	Fifth	127 (18.5)	52 (32.3) [5.1]	0 (0.0) [−7.4]	63 (34.4) [6.5]	12 (7.4) [−4.2]

Table 1. Cont.

	Total (<i>n</i> = 686)	Chile (<i>n</i> = 161)	Spain (<i>n</i> = 180)	Italy (<i>n</i> = 183)	Mexico (<i>n</i> = 162)
	<i>f_i</i> (%)	<i>f_i</i> (%) [R]	<i>f_i</i> (%) [R]	<i>f_i</i> (%) [R]	<i>f_i</i> (%) [R]
Socioeconomic level ***					
High	34 (5.0)	1 (0.6) [−2.9]	27 (15.0) [7.2]	5 (2.7) [−1.6]	1 (0.6) [−2.9]
Higher-middle	100 (14.6)	9 (5.6) [−3.7]	43 (23.9) [4.1]	48 (26.2) [5.2]	0 (0.0) [−6.0]
Middle	337 (49.1)	50 (31.1) [−5.2]	85 (47.2) [−0.6]	79 (43.2) [−1.9]	123 (75.9) [7.8]
Lower-middle	99 (14.4)	61 (37.9) [9.7]	21 (11.7) [−1.2]	17 (9.3) [−2.3]	0 (0.0) [−6.0]
Low	55 (8.0)	27 (16.8) [4.7]	2 (1.1) [−4.0]	4 (2.2) [−3.4]	22 (13.6) [3.0]
Don't know/No response	61 (8.9)	13 (8.1) [−0.4]	2 (1.1) [−4.3]	30 (16.4) [4.2]	16 (9.9) [0.5]
Employment status ***					
Employed	263 (38.3)	60 (37.3) [−0.3]	98 (54.4) [5.2]	71 (38.8) [0.1]	34 (21.0) [−5.2]
Unemployed	423 (61.7)	101 (62.7) [0.3]	82 (45.6) [−5.2]	112 (61.2) [−0.1]	128 (79.0) [5.2]
Financial autonomy *					
Fully dependent	406 (59.2)	95 (59.0) [−0.1]	97 (53.9) [−1.7]	103 (56.3) [−0.9]	111 (68.5) [2.8]
Covers <50% of expenses	153 (22.3)	26 (16.1) [−2.1]	54 (30.0) [2.9]	45 (24.6) [0.9]	28 (17.3) [−1.8]
Covers >50% of expenses	81 (11.8)	27 (16.8) [2.2]	21 (11.7) [−0.1]	21 (11.5) [−0.2]	12 (7.4) [−2.0]
Fully independent	46 (6.7)	13 (8.1) [0.8]	8 (4.4) [−1.4]	14 (7.7) [0.6]	11 (6.8) [0.0]
Domestic cohabitation ***					
With family members	575 (83.8)	130 (80.7) [−1.2]	165 (91.7) [3.3]	131 (71.6) [−5.2]	149 (92.0) [3.2]
With non-family members	111 (16.2)	31 (19.3) [1.2]	15 (8.3) [−3.3]	52 (28.4) [5.2]	13 (8.0) [−3.2]
Number of cohabitants ***					
One (living alone)	28 (4.1)	9 (5.6) [1.1]	7 (3.9) [−0.2]	3 (1.6) [−1.9]	9 (5.6) [1.1]
Two	87 (12.7)	18 (11.2) [−0.7]	21 (11.7) [−0.5]	34 (18.6) [2.8]	14 (8.6) [−1.8]
Three	155 (22.6)	40 (24.8) [0.8]	36 (20.0) [−1.0]	48 (26.2) [1.4]	31 (19.1) [−1.2]
Four	231 (33.7)	44 (27.3) [−1.9]	91 (50.6) [5.6]	47 (25.7) [−2.7]	49 (30.2) [−1.1]
Five or more	185 (27.0)	50 (31.1) [1.3]	25 (13.9) [−4.6]	51 (27.9) [0.3]	59 (36.4) [3.1]
Under treatment ***					
Medical	58 (8.5)	13 (8.1) [−0.2]	18 (10.0) [0.9]	20 (10.9) [1.4]	7 (4.3) [−2.2]
Psychological	72 (10.5)	12 (7.5) [−1.4]	11 (6.1) [−2.2]	39 (21.3) [5.6]	10 (6.2) [−2.1]
No	556 (81.0)	136 (84.5) [1.3]	151 (83.9) [1.1]	124 (67.8) [−5.4]	145 (89.5) [3.1]
On a special diet *					
Yes	51 (7.4)	8 (5.0) [−1.4]	15 (8.3) [0.5]	22 (12.0) [2.8]	6 (3.7) [−2.1]
No	635 (92.6)	153 (95.0) [1.4]	165 (91.7) [−0.5]	161 (88.0) [−2.8]	156 (96.3) [2.1]
Previously infected with COVID-19 ***					
Not to my knowledge	345 (50.3)	107 (66.5) [4.7]	62 (34.4) [−5.0]	70 (38.3) [−3.8]	106 (65.4) [4.4]
Based on self-administered test results	130 (19.0)	11 (6.8) [−4.5]	52 (28.9) [4.0]	43 (23.5) [1.8]	24 (14.8) [−1.5]
Diagnosed by a physician	211 (30.8)	43 (26.7) [−1.3]	66 (36.7) [2.0]	70 (38.3) [2.6]	32 (19.8) [−3.5]
Rest or restriction of physical activity during COVID-19 lockdown ***					
No	273 (39.8)	55 (34.2) [−1.7]	77 (42.8) [1.0]	64 (35.0) [−1.6]	77 (47.5) [2.3]
Associated with infection	110 (16.0)	24 (14.9) [−0.4]	17 (9.4) [−2.8]	41 (22.4) [2.7]	28 (17.3) [0.5]
Unrelated to COVID-19	211 (30.8)	72 (44.7) [4.4]	80 (44.4) [4.6]	50 (27.3) [−1.2]	9 (5.6) [−8.0]
Space limitations/lockdown circumstances	92 (13.4)	10 (6.2) [−3.1]	6 (3.3) [−4.6]	28 (15.3) [0.9]	48 (29.6) [6.9]
Pre- and post-pandemic physical activity level ***					
Much more PA now than before the pandemic	141 (20.6)	68 (42.2) [7.8]	28 (15.6) [−1.9]	25 (13.7) [−2.7]	20 (12.3) [−3.0]
More PA now	149 (21.7)	37 (23.0) [0.4]	39 (21.7) [0.0]	30 (16.4) [−2.0]	43 (26.5) [1.7]
Similar PA pre- and post-pandemic	208 (30.3)	28 (17.4) [−4.1]	58 (32.2) [0.6]	74 (40.4) [3.5]	48 (29.6) [−0.2]
Less PA now	140 (20.4)	24 (14.9) [−2.0]	39 (21.7) [0.5]	37 (20.2) [−0.1]	40 (24.7) [1.5]
Much less PA in the post-pandemic period	48 (7.0)	4 (2.5) [−2.6]	16 (8.9) [1.2]	17 (9.3) [1.4]	11 (6.8) [−0.1]
BMI-based weight status *					
Underweight	46 (6.7)	4 (2.5) [−2.4]	10 (5.6) [−0.7]	22 (12.0) [3.4]	10 (6.2) [−0.3]
Normal weight	434 (63.3)	102 (63.4) [0.0]	130 (72.2) [2.9]	117 (63.9) [0.2]	85 (52.5) [−3.3]
Overweight	168 (24.5)	45 (28.0) [1.2]	37 (20.6) [−1.4]	35 (19.1) [−2.0]	51 (31.5) [2.4]
Obese	38 (5.5)	10 (6.2) [0.4]	3 (1.7) [−2.6]	9 (4.9) [−0.4]	16 (9.9) [2.8]
Habitual PA level ***					
High	407 (59.3)	123 (76.4) [5.0]	112 (62.2) [0.9]	92 (50.3) [−2.9]	80 (49.4) [−2.9]
Moderate	166 (24.2)	30 (18.6) [−1.9]	50 (27.8) [1.3]	35 (19.1) [−1.9]	51 (31.5) [2.5]
Low	113 (16.5)	8 (5.0) [−4.5]	18 (10.0) [−2.7]	56 (30.6) [6.0]	31 (19.1) [1.0]

Note. Statistical significance in between-country comparisons was assessed using the chi-square test (***p* < 0.001; * *p* < 0.05). Abbreviations: *f_i* = absolute frequency; % = percentage; R = adjusted standardized residual; BMI = body mass index; PA = physical activity; DK/NA = do not know/no answer.

Overall, women represented 60.8% of the sample, although gender distribution differed significantly across country-based subsamples ($\chi^2(3) = 64.29$, $p < 0.001$; $V = 0.31$), highlighting heterogeneous sample composition.

Academic profile showed the most pronounced variation. Field of study differed markedly across countries ($\chi^2(21) = 1735.50$, $p < 0.001$; $V = 0.92$), consistent with the distinct disciplinary composition of participating universities. Academic year also varied significantly ($\chi^2(12) = 261.04$, $p < 0.001$; $V = 0.36$), with earlier years more frequent in Chile and later years more represented in Italy.

Differences were likewise observed in students' living and socioeconomic circumstances. Living arrangements ($\chi^2(3) = 37.44$, $p < 0.001$; $V = 0.23$) and household size ($\chi^2(12) = 53.84$, $p < 0.001$; $V = 0.16$) varied across subsamples. Perceived socioeconomic status showed substantial heterogeneity ($\chi^2(15) = 300.16$, $p < 0.001$; $V = 0.38$), accompanied by differences in employment status ($\chi^2(3) = 40.48$, $p < 0.001$; $V = 0.24$) and financial autonomy ($\chi^2(9) = 21.38$, $p = 0.011$; $V = 0.10$).

Health-related indicators also differed between country-based groups. Treatment status varied significantly ($\chi^2(6) = 38.96$, $p < 0.001$; $V = 0.17$), and adherence to medically prescribed diets was more common in Italy than in Mexico ($\chi^2(3) = 10.51$, $p = 0.015$; $V = 0.12$).

Country-based differences were additionally observed in COVID-19-related variables, including infection history ($\chi^2(6) = 67.95$, $p < 0.001$; $V = 0.22$) and restrictions to PA during lockdown periods ($\chi^2(9) = 122.42$, $p < 0.001$; $V = 0.24$).

Post-pandemic self-reported PA trajectories also differed across subsamples ($\chi^2(12) = 79.07$, $p < 0.001$; $V = 0.20$), as did compliance with World Health Organization PA recommendations ($\chi^2(6) = 62.29$, $p < 0.001$; $V = 0.21$). Significant differences were likewise found in BMI categories ($\chi^2(9) = 35.64$, $p < 0.001$; $V = 0.13$).

Additional cross-country variation was observed in age ($H(3) = 180.60$, $p < 0.001$, $\epsilon^2 = 0.26$), weekly working hours ($H(3) = 175.45$, $p < 0.001$, $\epsilon^2 = 0.48$), and PA indicators, including vigorous, moderate, and walking activity, as well as total MET expenditure (all $p < 0.01$).

Italian students were older on average, whereas participants from Chile, Spain, and Mexico were concentrated around 21 years of age. Weekly working hours were lowest among Mexican students. Differences also emerged across PA indicators. Chilean participants reported comparatively higher vigorous PA and total MET values, while BMI tended to be higher among Mexican students (Table 2).

Table 2. Descriptive statistics of continuous variables related to age, work, and physical activity levels by country.

	Total		Chile		Spain		Italy		Mexico	
	N	M $\pm$ SD	N	M $\pm$ SD	N	M $\pm$ SD	N	M $\pm$ SD	N	M $\pm$ SD
Age ***	685	22.41 $\pm$ 5.05	160	21.62 $\pm$ 2.85	180	20.96 $\pm$ 2.18	183	26.27 $\pm$ 7.62	162	20.43 $\pm$ 2.41
Hours worked per week ***	365	8.93 $\pm$ 12.15	51	14.60 $\pm$ 9.36	90	12.15 $\pm$ 8.39	62	13.17 $\pm$ 16.12	162	3.73 $\pm$ 10.93
METs-min/week spent on VPA ***	686	1970.33 $\pm$ 2325.86	161	2619.03 $\pm$ 2499.21	180	1736.27 $\pm$ 1963.43	183	1951.26 $\pm$ 2345.97	162	1607.23 $\pm$ 2384.60
METs-min/week spent on MPA ***	686	790.57 $\pm$ 1008.50	161	1040.99 $\pm$ 1061.06	180	502.13 $\pm$ 618.45	183	830.27 $\pm$ 1142.74	162	817.31 $\pm$ 1071.82
METs-min/week spent on walking **	686	1419.44 $\pm$ 1276.13	161	1649.51 $\pm$ 1363.66	180	1208.22 $\pm$ 1107.06	183	1639.36 $\pm$ 1458.65	162	1177.05 $\pm$ 1046.92
Total METs-min/week ***	686	4180.37 $\pm$ 3412.10	161	5309.56 $\pm$ 3784.12	180	3446.70 $\pm$ 2491.52	183	4420.89 $\pm$ 3631.06	162	3601.64 $\pm$ 3349.35
Body Mass Index ***	686	23.48 $\pm$ 6.70	161	24.16 $\pm$ 3.41	180	22.41 $\pm$ 3.17	183	22.43 $\pm$ 4.29	162	25.16 $\pm$ 11.90

Notes. Differences between countries were analysed using the Kruskal–Wallis test (*** $p < 0.001$; ** $p < 0.01$). Abbreviations: N = sample size; M = mean; SD = standard deviation; MET = metabolic equivalent of task; MET-min/week = metabolic equivalent minutes per week; VPA = vigorous physical activity; MPA = moderate physical activity.

Overall, these findings indicate substantial heterogeneity across country-based subsamples in sociodemographic, academic, contextual, and physical activity-related characteristics. To explore whether observed variation in physical activity level reflected disciplinary composition and related contextual factors, a complementary ordinal logistic regression model was estimated. The model showed acceptable fit (Pearson χ^2 $p = 0.197$; Deviance χ^2 $p = 1.000$), satisfied proportional-odds assumptions (test of parallel lines $p = 0.301$), and significantly improved upon the intercept-only model ($\chi^2(43) = 178.78$, $p < 0.001$; Nagelkerke $R^2 = 0.270$). When contextual and compositional variables were considered simultaneously, neither country nor academic programme emerged as statistically independent predictors of physical activity level. These findings suggest that the observed variability is more appropriately interpreted as arising from interacting contextual and behavioural conditions rather than isolated national or disciplinary effects.

3.2. Contextual Differences Across Country-Based Subsamples in Perceived Barriers

The number of perceived barriers to engaging in PA differed significantly across country-based subsamples. Kruskal–Wallis analysis indicated statistically significant variation ($H(3) = 64.261$, $p < 0.001$), with a moderate effect size ($\epsilon^2 = 0.09$).

The Mexican subsample showed the highest cumulative barrier burden ($M = 2.92$, $SD = 2.33$; mean rank = 433.93), followed by Italy ($M = 1.93$, $SD = 1.78$; mean rank = 361.84). Lower values were observed in Spain ($M = 1.29$, $SD = 1.58$; mean rank = 291.44) and Chile ($M = 1.34$, $SD = 1.76$; mean rank = 287.85).

Pairwise Mann–Whitney U comparisons with Bonferroni adjustment ($\alpha = 0.008$) further clarified these differences. The Mexican subsample presented significantly higher barrier burden than Chile ($Z = -6.465$, $p < 0.001$, $r = 0.36$), Spain ($Z = -6.709$, $p < 0.001$, $r = 0.36$), and Italy ($Z = -3.831$, $p < 0.001$, $r = 0.21$). Italian students likewise showed higher barrier burden than those from Chile ($Z = -3.721$, $p < 0.001$, $r = 0.20$) and Spain ($Z = -3.748$, $p < 0.001$, $r = 0.20$). No significant differences emerged between Chile and Spain ($Z = -0.357$, $p = 0.721$).

3.3. Sociodemographic and Contextual Correlates of Barrier Burden

Barrier burden varied according to several sociodemographic, academic, and contextual characteristics.

Gender differences reached statistical significance. Female students showed higher perceived barrier burden (mean rank = 362.73) than male students (mean rank = 312.30) ($U = 47,651.50$, $Z = -3.352$, $p = 0.001$), although the magnitude of the association was small ($r = 0.13$).

No significant differences were identified according to household composition ($U = 30,176.00$, $p = 0.433$), employment status ($U = 52,029.00$, $p = 0.157$), or adherence to a medically prescribed diet ($U = 14,566.00$, $p = 0.225$).

Academic variables displayed clearer patterns. Barrier burden differed across academic programmes ($H(7) = 64.057$, $p < 0.001$, $\epsilon^2 = 0.084$), indicating substantial variability across fields of study. Students enrolled in Social and Vocational Pedagogies and related programmes tended to present comparatively higher barrier levels. Differences across academic year were more modest ($H(4) = 11.239$, $p = 0.024$, $\epsilon^2 = 0.012$), with slightly higher burden observed among third-year students.

Several health-related and contextual variables were also associated with barrier burden. Students undergoing psychological treatment presented higher barrier levels than those receiving medical treatment or no treatment ($H(2) = 8.227$, $p = 0.016$, $\epsilon^2 = 0.009$). Likewise, restrictions to PA during lockdown periods were associated with increased barrier burden ($H(3) = 11.296$, $p = 0.010$, $\epsilon^2 = 0.012$).

The strongest association emerged for self-reported changes in PA following the pandemic ($H(4) = 59.693$, $p < 0.001$, $\epsilon^2 = 0.082$). Students describing reduced activity levels generally showed higher barrier burden than those reporting stable or increased activity. Habitual PA was similarly associated with perceived barriers ($H(2) = 34.517$, $p < 0.001$, $\epsilon^2 = 0.048$), with lower activity categories corresponding to higher barrier burden. BMI categories also showed statistically significant, although comparatively smaller, differences ($H(3) = 12.411$, $p = 0.006$, $\epsilon^2 = 0.014$), with higher burden observed among participants classified as obese or underweight.

To complement cumulative burden analyses and improve practical interpretability, prevalence of individual BBAQ domains was examined across country-based subsamples (Table 3). Significant between-country differences emerged for all seven domains (all χ^2 , $p < 0.001$), with effect sizes ranging from small to approaching moderate (Cramer's $V = 0.205$ – 0.293).

Table 3. Prevalence (%) of specific BBAQ barrier domains across national subsamples.

Barrier Domain	Total	Chile	Spain	Italy	Mexico	Chi-Square *	p	Cramer's V **
Lack of time	37.7	26.1 ↓	31.7	40.1	53.1 ↑	28.82	<0.001	0.205
Lack of social support	26.9	22.4	15.0 ↓	29.1	42.0 ↑	33.86	<0.001	0.222
Lack of energy	39.6	29.2 ↓	28.3 ↓	47.3 ↑	53.7 ↑	34.78	<0.001	0.225
Lack of willpower	35.6	20.5 ↓	32.8	35.7	53.7 ↑	39.79	<0.001	0.241
Fear of injury	8.5	6.2	4.4 ↓	4.9 ↓	19.1 ↑	31.52	<0.001	0.215
Lack of skills	12.7	6.8 ↓	7.8 ↓	11.5	25.3 ↑	32.38	<0.001	0.217
Lack of resources	24.8	22.4	9.4 ↓	24.2	45.1 ↑	58.94	<0.001	0.293

Note. Values represent the percentage of students reporting each BBAQ barrier domain. ↑ Adjusted standardized residual (ASR) > +1.96; ↓ ASR < −1.96, indicating over- or under-representation relative to expected frequencies. * Between-country differences were analysed using Pearson χ^2 tests. ** Cramer's V indicates effect size ($V \approx 0.10$ small, 0.30 moderate, 0.50 large).

Domain-level analyses revealed differentiated patterns across subsamples. Mexican students were over-represented across most barriers, as indicated by adjusted standardised residuals (ASR > +1.96), including lack of time (53.1%; ASR = 4.6), social support (42.0%; ASR = 5.0), energy (53.7%; ASR = 4.2), willpower (53.7%; ASR = 5.5), fear of injury (19.1%; ASR = 5.6), skills (25.3%; ASR = 5.5), and resources (45.1%; ASR = 6.8). Correspondingly, absence of these barriers was significantly under-represented within the Mexican subsample (ASR < −1.96).

Lower prevalence across several domains characterised Chilean and Spanish subsamples. Chilean students were under-represented in barriers related to time, energy, willpower, and skills, whereas Spanish students showed lower prevalence of social-support and resource barriers. Italian students presented comparatively higher prevalence of energy-related barriers (47.3%; ASR = 2.5), while differences across remaining domains were less pronounced.

Across the overall sample, lack of energy (39.6%), lack of time (37.7%), and lack of willpower (35.6%) were the most frequently reported barriers. Fear of injury (8.5%) and lack of skills (12.7%) appeared least prevalent. The strongest between-country association corresponded to lack of resources, followed by lack of willpower (see Table 3), indicating that resource-related and motivational barriers contributed prominently to subgroup differentiation.

3.4. CART Model: Hierarchical Profiles of Barrier Burden

The CART model examined hierarchical subgroup configurations of barrier burden using a binary outcome (Figure 1). The root node (Node 0) comprised the full sample ($n = 686$), with 67.8% classified as lower barrier burden and 32.2% as higher burden.

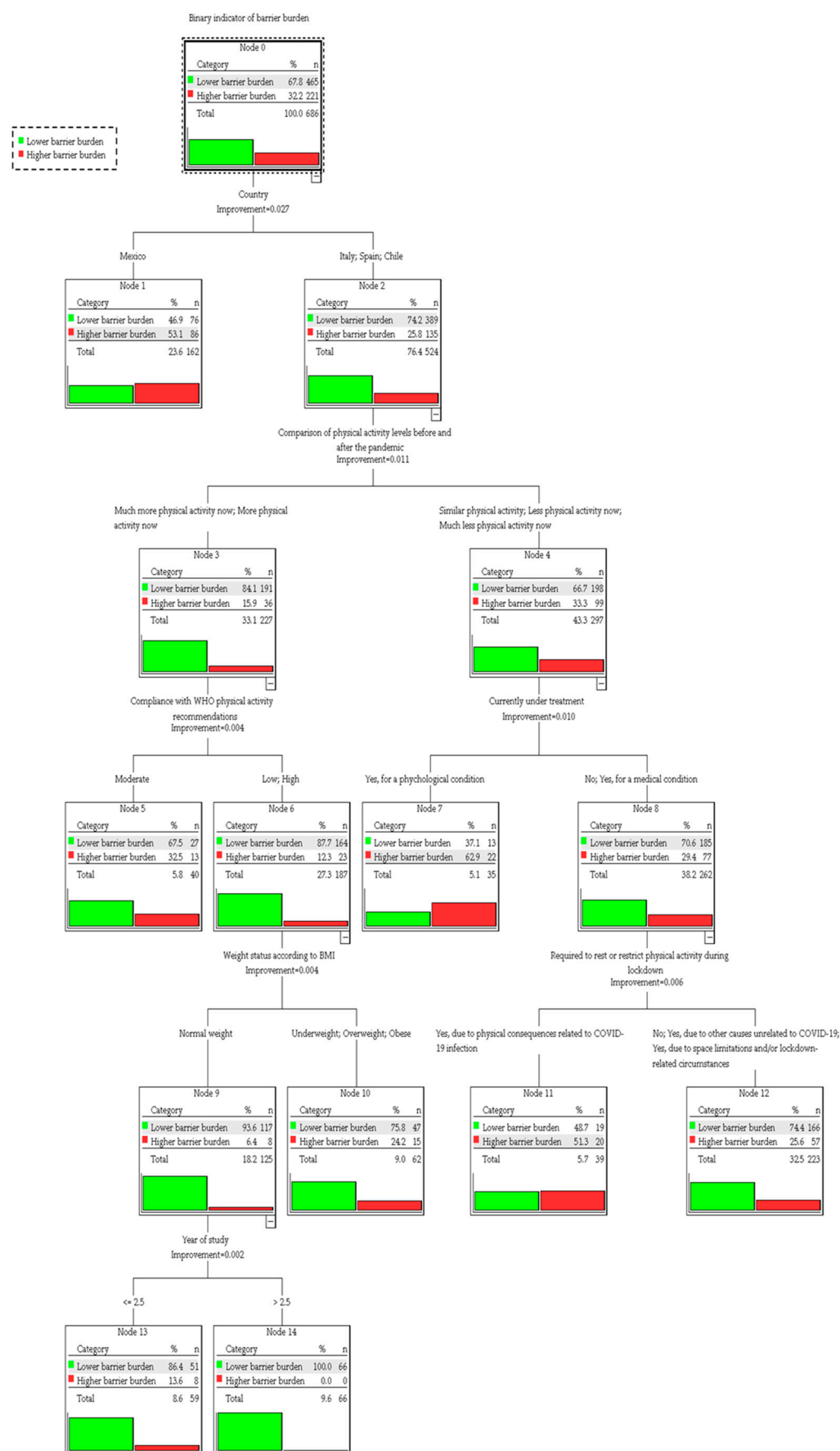


Figure 1. Decision tree (CART) showing hierarchical splits of barrier burden in university students.

Country emerged as the first segmentation variable (improvement = 0.027), providing the strongest initial partition within the analysed dataset. The Mexican subsample (Node 1; $n = 162$) concentrated the highest proportion of higher barrier burden (53.1%), whereas students from Italy, Spain, and Chile grouped in Node 2 ($n = 524$) showed substantially lower prevalence (25.8%).

Within Node 2, subgroup differentiation was further structured by self-reported post-pandemic PA trajectories (improvement = 0.011). Students reporting increased activity (Node 3; $n = 227$) presented comparatively lower barrier burden (15.9%), while those describing stable or reduced activity formed Node 4 ($n = 297$), where higher burden was more frequent (33.3%).

Among students in Node 3, habitual PA provided additional differentiation (improvement = 0.004). Moderate activity (Node 5; $n = 40$) corresponded to higher barrier burden (32.5%), whereas low or high activity levels grouped in Node 6 ($n = 187$) were associated with lower prevalence (12.3%). BMI contributed further refinement (improvement = 0.004). Students with normal BMI (Node 9; $n = 125$) showed particularly low barrier burden (6.4%), compared with underweight, overweight, or obese students (Node 10; $n = 62$), where prevalence reached 24.2%.

Academic progression provided an additional split within Node 9 (improvement = 0.002). Students in earlier years of study (≤ 2.5 years; Node 13; $n = 59$) showed 13.6% higher barrier burden, whereas no higher-burden cases were identified among those in later years (> 2.5 years; Node 14; $n = 66$).

A different configuration emerged within Node 4, where treatment status represented the next segmentation variable. Students undergoing psychological treatment (Node 7; $n = 35$) concentrated one of the highest levels of barrier burden (62.9%), compared with peers receiving medical treatment or no treatment (Node 8; $n = 262$; 29.4%). Lockdown-related restrictions provided further differentiation (improvement = 0.006): COVID-related physical restrictions (Node 11; $n = 39$) were associated with higher barrier prevalence (51.3%) than other forms of restriction (Node 12; $n = 223$; 25.6%).

Model performance indicated moderate stability (resubstitution risk = 0.293, SE = 0.017; cross-validated risk = 0.315, SE = 0.018), with overall classification accuracy of 70.7%. Performance was stronger for lower barrier burden, correctly identifying 76.8% of cases (357/465), whereas identification of higher barrier burden reached 57.9% (128/221). These results suggest greater precision in distinguishing lower-burden configurations while maintaining moderate discrimination of higher-burden subgroups. Because some terminal nodes contained comparatively small samples, their interpretation should be considered exploratory.

Figure 2 presents the relative importance of predictors within the CART model. Country contributed most strongly to initial segmentation, followed by academic programme and habitual PA level. Post-pandemic PA trajectories and treatment-related variables showed intermediate importance, whereas sociodemographic variables contributed comparatively less to subgroup differentiation.

3.5. CHAID Model: Hierarchical Profiles of Barrier Burden

The Exhaustive CHAID model examined subgroup segmentation using the three-level barrier burden outcome (Figure 3). The root node (Node 0) included 685 students, of whom 52.3% were classified as low barrier burden, 28.9% as moderate, and 18.8% as high.

Consistent with the CART model, country emerged as the first segmentation variable (adjusted $p < 0.001$; $\chi^2 = 69.352$; $df = 4$). Three distinct branches were identified. The Mexican subsample (Node 2; $n = 162$) concentrated the largest proportion of high barrier burden (38.3%). Italian students (Node 1; $n = 182$) displayed a more balanced distribution across categories (47.3% low, 34.6% moderate, and 18.1% high), whereas students from

Spain and Chile grouped in Node 3 ($n = 341$) predominantly within the low-barrier category (63.6%), with only 10.0% classified as high.

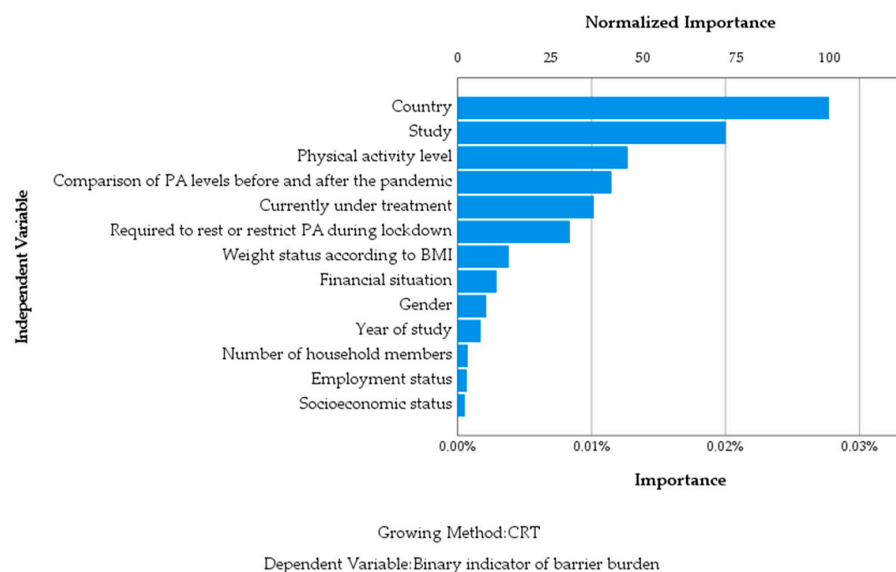


Figure 2. Relative importance of predictors in the CART model for barrier burden among university students.

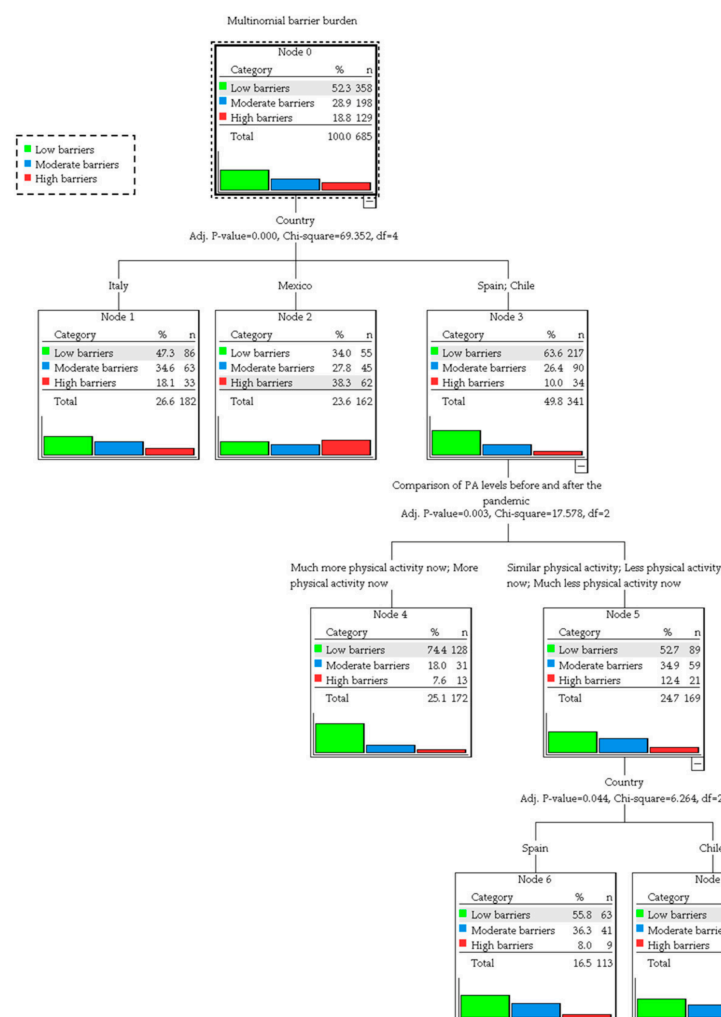


Figure 3. Exhaustive CHAID decision tree illustrating multinomial barrier burden profiles.

Within the Spain–Chile branch, subgroup differentiation was structured by self-reported post-pandemic PA trajectories (adjusted $p = 0.003$; $\chi^2 = 17.578$; $df = 2$). Students reporting increased activity (Node 4; $n = 172$) clustered mainly in the low-barrier category (74.4%), with relatively few high-barrier cases (7.6%). By contrast, those describing stable or reduced activity (Node 5; $n = 169$) more frequently occupied the moderate category (34.9%).

A final split, again involving country (adjusted $p = 0.044$; $\chi^2 = 6.264$; $df = 2$), differentiated Spanish and Chilean subsamples. Spain (Node 6; $n = 113$) showed predominance of low barriers (55.8%), followed by moderate (36.3%) and high levels (8.0%), whereas the Chilean branch (Node 7; $n = 56$) displayed a comparatively greater proportion of higher burden (21.4%).

Model performance indicated moderate stability (resubstitution risk = 0.467, SE = 0.019; cross-validated risk = 0.470, SE = 0.019), with overall classification accuracy of 53.3%. Classification was strongest for the low-barrier category (84.6%), moderate for high barriers (48.1%), and comparatively limited for the intermediate category. This pattern is consistent with the tendency of CHAID to prioritise dominant category separation, which may constrain discrimination of moderate subgroups.

Although the CHAID model improved proportional-by-chance (base-rate) classification, the gain was modest (+1.0 percentage point). Its value therefore lies primarily in supporting subgroup segmentation and hierarchical pattern identification rather than predictive optimisation or high-precision classification.

3.6. Convergence of CART and CHAID Findings

Considered jointly, the CART and Exhaustive CHAID models revealed broadly consistent patterns in the hierarchical organisation of perceived barriers to PA.

CART produced higher overall classification performance and greater structural detail, whereas CHAID generated more parsimonious subgroup configurations. Despite these analytical differences, both approaches converged on similar segmentation patterns. Country emerged as the initial partitioning variable in both models, and self-reported post-pandemic PA trajectories further differentiated subgroup configurations within these contextual branches.

Cross-validation results were comparable to resubstitution estimates across models, suggesting moderate stability of the identified structures within the analysed sample.

Several subgroup patterns appeared consistently across both approaches. Higher barrier burden was concentrated among Mexican students and among individuals reporting stable or reduced PA following the pandemic period. In contrast, lower barrier burden was more commonly observed among students describing increased post-pandemic PA.

To facilitate interpretation and improve readability of the decision-tree findings, Table 4 summarises the principal terminal-node configurations identified by CART and Exhaustive CHAID. The table synthesises subgroup characteristics, sample size, and corresponding barrier-burden patterns across both analytical approaches. These summaries are intended to characterise context-sensitive subgroup configurations derived from exploratory segmentation rather than deterministic or high-precision classifications.

Table 4. Summary of terminal-node configurations identified by CART and Exhaustive CHAID models.

Model	Terminal Node	Main Subgroup Characteristics	<i>n</i>	Barrier Burden	Interpretive Profile
CART	Node 9	Increased PA + normal BMI	125	Very low	Most favourable configuration
CART	Node 10	Increased PA + non-normal BMI	62	Moderate	Context-dependent favourable configuration

Table 4. *Cont.*

Model	Terminal Node	Main Subgroup Characteristics	<i>n</i>	Barrier Burden	Interpretive Profile
CART	Node 7	Psychological treatment + stable/reduced PA	35	Very high	Higher-burden psychological-treatment configuration
CART	Node 11	COVID-related restriction	39	High	Restriction-related configuration
CHAID	Node 2	Mexican students	162	High	Higher-burden contextual profile
CHAID	Node 1	Italian students	182	Moderate	Intermediate contextual configuration
CHAID	Node 4	Spain/Chile + increased PA	172	Low	Favourable post-pandemic trajectory configuration
CHAID	Node 5	Spain/Chile + stable/reduced PA	169	Moderate	Less favourable trajectory configuration

Note. Profiles summarise terminal-node configurations derived from exploratory decision-tree segmentation and should be interpreted as context-sensitive subgroup patterns rather than deterministic or predictive classifications.

4. Discussion

The present study identified differentiated configurations of perceived barriers associated with insufficient physical activity (IPA) among university students using complementary decision-tree approaches. These configurations should not be interpreted as direct profiles of physical inactivity. Rather, they represent empirically derived patterns of barrier burden linked to differing behavioural and contextual circumstances within university populations.

Across both CART and Exhaustive CHAID models, similar hierarchical structures emerged. Country-based subsamples and self-reported post-pandemic PA trajectories consistently shaped subgroup differentiation, suggesting that perceived barriers are not distributed uniformly but instead cluster within specific contextual and behavioural configurations. This pattern aligns with previous research describing considerable heterogeneity in PA-related constraints during university years (Aceijas et al., 2017; Castro et al., 2018; Edelmann et al., 2022).

At the same time, the prominence of country as the initial segmentation variable requires careful interpretation. In the present study, country should not be understood as a direct indicator of independent national or cultural effects. Recruitment procedures, institutional settings, and disciplinary composition differed across participating universities and were closely intertwined with country-based subsamples. Consequently, the first tree split is better interpreted as a contextual segmentation feature rather than evidence of autonomous country-level influences.

This distinction is particularly relevant when interpreting cross-country comparisons. The observed configurations likely reflect overlapping institutional, sociocultural, and academic conditions rather than discrete national differences. Although country contributed strongly to subgroup partitioning, the present design does not permit disentangling broader contextual influences from programme composition or recruitment-related characteristics. The identified patterns are therefore more appropriately understood as context-bound subgroup configurations.

Complementary analyses reinforced this cautious interpretation. To examine whether cross-country variation in physical activity reflected disciplinary composition and related contextual factors, an adjusted ordinal logistic regression model was estimated including academic programme alongside country, gender, BMI, and related sociodemographic variables. The model showed adequate fit and met proportional-odds assumptions. When these factors were considered simultaneously, neither country nor academic programme

emerged as statistically independent predictors within the adjusted model. Rather than indicating discrete national or disciplinary effects, the observed variability appears more appropriately understood as arising from interacting contextual and behavioural conditions. Nevertheless, interpretation remains constrained by sample composition and sparse category overlap.

The convergence between CART and CHAID reinforces this interpretation. Despite differing analytical logics, both approaches identified comparable structuring variables and subgroup patterns. CART generated more detailed hierarchical differentiation, whereas CHAID produced broader and more parsimonious configurations. Viewed together, the models suggest moderate stability in the observed segmentation patterns while highlighting the value of complementary decision-tree approaches for exploring heterogeneity within behavioural data (Breiman et al., 1984; Kass, 1980; Lemon et al., 2003).

Importantly, these findings should not be interpreted in predictive terms. The decision-tree models were not intended as high-precision classification tools or as instruments for forecasting physical inactivity. Their contribution lies primarily in identifying how contextual and behavioural characteristics cluster within university populations and in generating exploratory hypotheses regarding variability in perceived barriers. This interpretation is consistent with the modest improvement over baseline classification observed particularly in the CHAID model and supports viewing both approaches as segmentation-oriented and hypothesis-generating rather than predictive frameworks.

The examination of individual BBAQ domains provided additional insight into how perceived barriers are configured within university populations. While cumulative barrier burden offered a parsimonious indicator suitable for hierarchical segmentation, domain-level analyses revealed meaningful variation in the composition of these barriers across country-based subsamples.

Across the overall sample, lack of energy, lack of time, and lack of willpower emerged as the most prevalent barriers, whereas fear of injury and lack of skills appeared comparatively infrequent. This pattern is consistent with previous research identifying motivational and time-related constraints among the most commonly reported obstacles to PA participation in university students (Ilić et al., 2022; Martínez-Lemos et al., 2014; Sevil et al., 2017; Sukys et al., 2019). The present findings extend this literature by showing not only that such barriers are prevalent, but also that they cluster differently across subgroup configurations.

Domain-specific analyses further clarified these differences. Mexican students displayed comparatively higher prevalence across most barrier domains, particularly those related to time, energy, willpower, and resources. However, these findings should again be interpreted cautiously. As discussed above, country in the present study represents a contextual sample characteristic rather than an independent national effect. Consequently, these patterns are better understood as context-bound configurations shaped by overlapping institutional, academic, and sociocultural conditions.

The prominence of time-, energy-, and resource-related barriers aligns with socioecological interpretations of PA behaviour (Sallis et al., 2008). Rather than reflecting isolated personal limitations, perceived barriers appear embedded within broader educational and social environments. Time constraints and fatigue, for example, may relate to competing academic demands and lifestyle pressures typical of emerging adulthood, whereas resource-related barriers may reflect differences in access, institutional support, or opportunities for participation.

The particularly strong association observed for lack of resources is notable in this regard. Among the seven BBAQ domains, resource-related barriers displayed the strongest between-country association, suggesting that environmental and organisational conditions may contribute substantially to subgroup variability. Previous studies have similarly high-

lighted the role of accessibility, institutional environments, and supportive infrastructures in shaping PA engagement among university students (Murphy et al., 2024; Paulo et al., 2024; Zhang et al., 2022).

Viewed through the Health-Promoting Universities framework, these findings reinforce the importance of approaching PA promotion as an institutional and contextual issue rather than solely as a matter of individual responsibility (Sánchez-Ordóñez & Gimeno-Navarro, 2025). Universities are not simply settings in which health behaviours occur; they are environments capable of facilitating or constraining opportunities for active lifestyles. From this perspective, strategies addressing clustered contextual barriers may be more consistent with student realities than approaches focused exclusively on motivation or personal choice.

At the same time, the comparatively low prevalence of fear of injury and lack of skills suggests that barriers within university populations may be less closely related to physical competence or safety concerns than to organisational, motivational, and environmental conditions. This distinction is relevant because it points toward different priorities for health promotion across populations and settings.

Post-pandemic PA trajectories also emerged as an important source of subgroup differentiation. Students reporting increased activity generally clustered within lower-barrier configurations, whereas stable or reduced activity was more often associated with higher barrier burden. These findings are broadly consistent with previous evidence describing shifts in PA patterns following pandemic-related disruptions and changes in daily routines (López-Valenciano et al., 2021; Motevalli et al., 2023).

Nevertheless, interpretation of these patterns requires caution. The present study relied on retrospective self-report and therefore cannot determine whether observed differences reflect enduring pandemic influences, broader developmental transitions, or other contextual changes accompanying progression through university life. Rather than representing direct pandemic effects, these trajectories are more appropriately interpreted as subjective indicators of behavioural change relative to that period.

Psychological and behavioural factors may provide additional insight into subgroup variability. Higher barrier burden among students undergoing psychological treatment is compatible with research linking motivational regulation, self-efficacy, and emotional wellbeing to PA engagement (Brown et al., 2024; Porter et al., 2024). In this context, perceived barriers may reflect not only external constraints but also differences in behavioural regulation and perceived capacity to maintain active routines (Rhodes, 2021).

Taken together, these findings support a context-sensitive interpretation of perceived barriers. The observed differences were not characterised by uniform increases across all domains but were driven primarily by time-, energy-, motivational-, and resource-related barriers. This pattern suggests that variability in PA-related constraints may be better understood through clustered contextual and behavioural conditions rather than isolated individual deficits.

A further contribution of the present study lies in the use of complementary decision-tree approaches to examine variability in perceived barriers. CART and Exhaustive CHAID provided distinct but convergent perspectives on subgroup organisation. CART generated more detailed hierarchical differentiation, while CHAID offered a more parsimonious overview of broader configurations. Their convergence strengthens confidence in the stability of the observed structures and highlights the potential value of segmentation-oriented approaches for exploring heterogeneous university populations (Breiman et al., 1984; Kass, 1980; Lemon et al., 2003).

These methodological contributions should nevertheless be interpreted with restraint. Although both models supported subgroup characterisation, their classification

performance—particularly in the case of CHAID—showed only modest improvement over baseline estimation. Accordingly, the decision trees are better understood as exploratory analytical tools designed to identify hierarchical configurations and generate hypotheses rather than as practically deployable or high-precision classification systems.

From a health-promotion perspective, the findings underscore the importance of recognising variability within university populations. Emerging adulthood represents a developmental period during which behavioural routines may consolidate, while university environments shape opportunities, constraints, and patterns of participation. The present findings therefore suggest that PA promotion may benefit from considering how barriers cluster within specific student contexts rather than assuming homogeneous needs or experiences.

This interpretation is compatible with socioecological and Health-Promoting Universities perspectives, which emphasise the interaction between behavioural and environmental influences (Sallis et al., 2008; Sánchez-Ordóñez & Gimeno-Navarro, 2025). Within the present study, contextual and behavioural variables—including country-based environments, academic programme, and PA trajectories—contributed more prominently to subgroup differentiation than traditional sociodemographic characteristics. Such findings reinforce the relevance of institutional and contextual conditions when examining PA-related barriers in higher education.

The cross-sectional design does not permit causal inference and relies primarily on self-reported information, introducing the possibility of reporting bias. Recruitment through convenience sampling further shaped the composition of the study sample and generated substantial overlap between country, institutional setting, and disciplinary profile. Because academic programme equivalence across countries was not sought, observed cross-country differences cannot be interpreted as isolated national effects and may partly reflect institutional or programme-related characteristics.

Although complementary adjusted analyses were conducted to explore the potential influence of disciplinary composition and related contextual factors, the substantial overlap between country, institutional setting, and academic programme, together with sparse category combinations, limits interpretation of fully independent contextual effects. These analyses suggested that neither country nor academic programme independently accounted for variation in physical activity level, reinforcing the need to interpret subgroup differences as contextually embedded rather than attributable to isolated national or disciplinary influences.

Additional contextual influences should also be acknowledged. Seasonal and climatic conditions were not formally controlled and may have affected both PA patterns and perceived barriers across settings. Likewise, the post-pandemic PA variable relied on retrospective self-report and may reflect recall bias as well as broader developmental or educational transitions unrelated to the pandemic itself. Accordingly, this measure is more appropriately interpreted as a subjective behavioural trajectory indicator rather than as evidence of direct or enduring pandemic effects.

Methodological limitations related to measurement and classification procedures also warrant consideration. Although the IPAQ-SF remains widely used in epidemiological research, its criterion validity relative to objective measures is modest and PA levels may be overestimated (Lee et al., 2011). In addition, formal measurement invariance testing of the BBAQ-21 across participating countries was not conducted, and the original ≥ 5 barrier threshold has not been specifically validated for university populations in Chile, Mexico, Spain, or Italy. These issues limit confidence in strict cross-country comparability and suggest that subgroup classifications should be interpreted as exploratory and context-sensitive rather than psychometrically equivalent across settings.

Finally, decision-tree structures reflect hierarchical partitioning within the analysed sample rather than independent explanatory effects. Although cross-validation procedures and minimum node-size constraints were implemented to reduce overfitting, some terminal nodes involved relatively small subgroups. Consequently, these configurations should be interpreted as exploratory patterns requiring confirmation in larger and more balanced international samples.

Despite these limitations, the present study contributes to understanding how perceived barriers to PA cluster within university populations. Rather than identifying direct profiles of physical inactivity, the findings characterise differentiated and context-dependent configurations of barrier burden. The combined use of CART and CHAID, together with domain-specific analyses, offers a structured and exploratory perspective on variability in PA-related constraints and may support future research seeking to examine how institutional, behavioural, and environmental conditions interact in higher education settings.

5. Conclusions

This study identified differentiated and context-dependent configurations of perceived barriers associated with insufficient physical activity among university students. Rather than describing direct physical inactivity profiles, the findings characterise how perceived barriers cluster within distinct behavioural and contextual subgroup patterns. Higher barrier burden was more commonly observed among students reporting stable or reduced post-pandemic physical activity and within comparatively less favourable contextual configurations.

The combined use of CART and Exhaustive CHAID offered complementary perspectives on subgroup variability, supporting an exploratory understanding of how contextual and behavioural factors interact in relation to perceived barriers. Although these models are not intended as high-precision classification tools, they provided a structured approach for examining heterogeneity within university populations.

Complementary adjusted analyses further suggested that observed variability is unlikely to reflect independent national or disciplinary effects. Instead, subgroup differences appear more appropriately understood as contextually embedded configurations arising from interacting behavioural, institutional, and sociocultural conditions.

From a context-informed health promotion perspective, the findings reinforce the importance of considering clustered barriers and contextual conditions when addressing physical activity in higher education settings. Rather than supporting uniform or implementation-ready profiles, the identified configurations may offer preliminary insight into how barriers are organised within diverse university environments.

These conclusions should be interpreted within the methodological scope of exploratory multicountry profiling, recognising limitations related to self-reported measures, cross-sectional design, and the absence of formal psychometric equivalence testing across countries. Future research using longitudinal and more balanced international samples may help clarify how perceived barriers evolve and interact across university environments over time.

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Abbreviations

The following abbreviations are used in this manuscript:

ASR	Adjusted Standardized Residual
BBAQ-21	Barriers to Being Active Questionnaire (21 items)
BMI	Body Mass Index
CART	Classification and Regression Trees
CHAID	Chi-square Automatic Interaction Detection
HPU	Health-Promoting Universities
ICC	Intraclass Correlation Coefficient
IPA	Insufficient Physical Activity
IPAQ-SF	International Physical Activity Questionnaire–Short Form
MET	Metabolic Equivalent of Task
MET-min/week	Metabolic Equivalent of Task minutes per week
MPA	Moderate Physical Activity
PA	Physical Activity
SD	Standard Deviation
VPA	Vigorous Physical Activity
WHO	World Health Organization

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