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Wearable Device Feedback in Physical Education: A Narrative Review of Movement Load Monitoring, Motor Skill Learning and Student Engagement

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Abstract (Structured)

Background. Wearable devices are entering physical education (PE) from elite sport. The question is not whether they can measure students, but whether their feedback changes what students do and learn.

Aim. This review maps the devices and metrics used in PE, appraises measurement trustworthiness, and examines how far device feedback translates into movement load and learning outcomes.

Material and methods. PubMed and related sources were searched to September 2026 for studies of wearables and feedback in PE; peer-reviewed studies and reviews were prioritised and synthesised narratively.

Results. Devices in PE span accelerometers, wrist-worn heart rate sensors, inertial measurement units and smartphone systems. Step counting and heart rate are acceptably accurate; energy expenditure estimation is not. Feedback is mostly visual, concurrent and descriptive, rarely grounded in learning theory. Feedback improves motor skill learning versus no feedback, but evidence on format and timing is limited. Device-supported PE yields consistent short-term gains in moderate-to-vigorous activity, but effects on motivation are inconsistent. Evidence favours male, able-bodied and advantaged populations.

Conclusions. Device feedback is promising but under-theorised in PE; accuracy, feedback design and pedagogy jointly determine whether data become learning. Future work should treat feedback design as an explicit variable and assess learning rather than device-derived activity.

Key words: wearable devices; physical education; feedback; motor learning; physical activity; student engagement

1. Introduction

Physical education (PE) occupies a uniquely favourable position in the school day: it is the only curricular context in which the whole student cohort is expected to move, and it reaches young people irrespective of prior sporting commitment or family circumstance (Silva et al., 2018). It is therefore repeatedly positioned as a public health lever. That position, however, rests on an assumption that is only partly supported.

Objectively measured activity during PE lessons is typically modest. In a Swedish study of 39 lessons across three grade levels, approximately 25% of lesson time was spent in moderate-to-vigorous physical activity (MVPA), and the proportion varied markedly with lesson content, ranging up to roughly one third during fitness and orienteering lessons (Fröberg et al., 2017).

Comparable patterns of content-dependent activity have been reported elsewhere (Kremer et al., 2012), and developmental trajectories suggest that activity accrual during PE does not automatically improve as students progress through school (Cheval et al., 2016). The same conclusion emerges from the school day as a whole: accelerometer-based evidence shows that recess and other non-curricular segments contribute substantially but inconsistently to daily activity (Pulido Sánchez & Iglesias Gallego, 2021).

PE thus represents a high-reach but low-yield setting, and the question of how to raise its yield is an enduring one.

Raising that yield is not solely a question of intensity. Interventions designed to improve the quality of PE have produced small-to-moderate effects across psychomotor, cognitive, affective and social learning domains; a meta-analysis of 135 studies with more than 42,500 participants reported a mean effect of d = 0.32, rising to approximately 0.40 after adjustment for publication bias (Dudley et al., 2022).

The institutional features that constitute quality PE — curricular time, class size, facilities and assessment policy — are largely beyond the individual teacher's control (Burson et al., 2021). What remains within the teacher's control is the instructional process, and within that process feedback is one of the most powerful and most modifiable levers.

A systematic review of 23 studies conducted in PE lessons found strong evidence that feedback interventions improve students' motor skill learning compared with no feedback, while evidence on the comparative merits of different feedback formats and contents was limited or mixed (Zhou et al., 2021).

This distinction matters for the argument developed in the present review: feedback has a defensible evidence base as a pedagogical mechanism, even where the optimal configuration of that feedback remains unresolved.

Against this background, the past decade has seen a rapid expansion of digital measurement in education, and PE has been drawn into it. The literature now routinely describes data-driven pedagogy, intelligent PE systems and the governance of student physical health through large-scale data infrastructures (Deng et al., 2022; Wu, 2025; Yue, 2022).

Wearable devices are the most visible entry point of this movement into the gymnasium, because they promise something that has always been pedagogically attractive: an objective, continuous, individualised view of what each student is actually doing.

Students themselves appear receptive. In a survey of 428 Chinese college students, perceived usefulness, perceived ease of use, innovation and curiosity, health needs and social motivation

all positively predicted the use of sports smart wearable devices, with technology readiness moderating these relationships; notably, privacy concerns also entered the model as a significant term rather than as a background worry (Wu et al., 2026).

A meta-analysis of 24 studies with 7,180 respondents similarly found that perceived usefulness is positively associated with fitness wearable adoption, with the strength of that association moderated by cultural background, gender and the pandemic context (Shi et al., 2022).

A cross-sectional study of 1,286 students across six Chinese universities found that wearable sports equipment was associated with exercise persistence, mediated by exercise motivation and moderated by social support (Han et al., 2025). The evidence on whether device use translates into sustained activity is nonetheless more guarded at the level of pooled trials.

A systematic review and meta-analysis of randomised trials in children and adolescents concluded that the effects of wearable activity trackers on physical activity in young populations remain uncertain (Au et al., 2024), and an earlier systematic review of 33 studies found largely mixed evidence for increases in steps and MVPA, alongside qualitative reports of increased motivation through self-monitoring, goal setting,

feedback and competition — but also of technical difficulties and novelty effects (Creaser et al., 2021).

A recent systematic review published in this journal similarly reported acceptable accuracy for step counting and heart rate but poor accuracy for energy expenditure, and observed that pooled effects favouring wearable interventions in adults were not replicated in youth populations (Grzybowska et al., 2026).

Taken together, the literature supports two internally consistent claims that are frequently conflated. The first is that wearable devices can measure selected aspects of movement with acceptable accuracy and can be used profitably in PE. The second is that the mere presence of devices, or of the data they produce, improves learning. The first is reasonably well established; the second is not.

The gap between them is educational rather than technological, and it is a gap about feedback: whether students receive information about their movement that they can understand, act on and internalise, and whether teachers receive information that changes what they teach.

The present review addresses that gap. Its objectives are to map the device classes and metrics currently used in PE; to appraise the quality and interpretability of the measurements on which feedback depends; to describe the feedback designs actually employed and the theoretical frameworks that might organise them;

and to evaluate the evidence linking device-supported feedback to movement load, motor skill learning and student engagement.

A secondary aim is to identify the populations, settings and outcome domains in which the evidence is thinnest, since these define the most defensible contribution of a new empirical study.

2. Research Materials and Methods

This is a narrative review. Narrative synthesis was chosen because the guiding question — how device-generated feedback functions pedagogically in PE — spans measurement science, motor learning and motivational psychology, a combination for which formal pooling across a single effect-size metric would be inappropriate and potentially misleading.

The review was prepared in accordance with published recommendations for the reporting of narrative reviews, and the selection and interpretation of sources is described transparently below so that readers can judge the basis of each synthesis.

Search strategy. Bibliographic searches were carried out in PubMed and supplementary bibliographic sources from database inception to September 2026. Search strings combined three concept blocks. The device block comprised wearable, wearables, wearable technology, wearable device, smartwatch, fitness tracker, activity tracker, accelerometer, inertial measurement unit, IMU, microtechnology, pedometer and heart rate monitor.

The setting block comprised physical education, physical education lesson, PE class, school, secondary school, university students, college students and undergraduate.

The outcome block comprised feedback, augmented feedback, real-time feedback, visual feedback, auditory feedback, haptic feedback, biofeedback, motor learning, motor skill, skill acquisition, training load, workload, physical activity, motivation, self-determination, self-efficacy and engagement. Terms were searched in title and abstract fields.

Eligibility and selection. Peer-reviewed articles were eligible if they concerned the use of a wearable or body-worn sensor device, or of feedback derived from such a device, in a physical education, school sport or closely comparable instructional setting; or if they addressed the measurement properties, feedback design or pedagogical implementation of such devices.

Priority was given to systematic reviews, meta-analyses and randomised or quasi-experimental studies in students, and to studies published in the most recent decade. Studies concerning exclusively clinical rehabilitation populations were considered only where they contributed directly to the understanding of feedback design.

Titles and abstracts were screened, full texts of potentially relevant records were examined, and the reference lists of included reviews were screened for additional sources. No formal risk-of-bias appraisal was applied, consistent with the narrative design; instead, study design, sample and population are reported at the point of citation so that the strength of each claim is visible to the reader.

Synthesis. Findings were organised around four questions: what devices measure in PE and how well; how feedback derived from those devices is designed; through which mechanisms it is proposed to act; and what outcomes have actually been demonstrated for movement load, motor skill learning and engagement. Numerical pooling was not performed, and the review does not present itself as a systematic review or meta-analysis.

3. Research Results

The findings are presented in nine parts. The first two concern the instruments themselves — what is measured in a PE setting and how trustworthy those measurements are.

The following seven address the pedagogical layer: how feedback derived from devices is currently designed, the mechanisms through which it is proposed to act, and the evidence for effects on movement load, motor skill learning, engagement, equity, teaching practice and ethical acceptability.

3.1. Device Classes and Metrics in the PE Context

The devices used in PE research are best understood as three overlapping families, distinguished by what they quantify rather than by their form factor.

The first family is *activity and movement volume*. Accelerometers, pedometers and their consumer equivalents estimate step counts, activity counts, time spent in intensity bands and, by extrapolation, MVPA. This family underpins the largest share of school-based research, because its outputs map directly onto the MVPA targets that structure school physical activity policy.

In a multinational study of 5,874 children in twelve countries, accelerometry revealed that only about one quarter of children reported attending PE three or more times per week, and that the association between PE attendance and daily activity varied by national income level (Silva et al., 2018). Accelerometry has also been used to characterise activity across segments of the school day and to identify which segments respond to intervention (Cradock et al., 2014; Pulido Sánchez & Iglesias Gallego, 2021).

The second family is *physiological and internal load*. Wrist-worn optical heart rate sensors and chest straps estimate cardiovascular intensity, and heart rate-derived indices are used as proxies

for internal training load. Because heart rate is interpretable in real time with minimal processing, this family has particular pedagogical appeal: a student can see intensity as it happens.

The third family is *movement quality and external load*. Inertial measurement units and, increasingly, smartphone cameras with pose-estimation algorithms quantify jumps, accelerations, changes of direction and segment kinematics. In team sport research this family has been the dominant topic of wearable investigation.

A systematic review of accelerometry for external workload monitoring identified 118 eligible studies, in which devices were most often worn on the scapulae, most often manufactured by a single commercial provider, and most often used to derive a proprietary composite load variable; rugby, Australian football, soccer and basketball predominated, and the samples were overwhelmingly male and professional or elite (Gómez-Carmona et al., 2020).

A scoping review of 407 studies reached a closely similar conclusion: two thirds of studies concerned soccer, rugby or Australian football, 81% concerned male athletes and 74% concerned elite or professional competition (Benson et al., 2020). In other words, the wearable literature that is most technically mature is also the least representative of a PE class, and the translation of these methods into educational settings cannot be assumed.

Where that translation has been attempted in basketball — a sport central to many school and university curricula — studies have used wearable devices for posture monitoring during training (Ma & Hao, 2022) and inertial measurement units to quantify jump count, jump height and a proposed tendon-load-weighted jump height in youth players (Benson et al., 2021).

Reviews of wearable applications in sport have likewise concentrated on training and performance contexts rather than on instructional settings, with endurance training and team sport workloads forming the principal areas of synthesis (Zhang et al., 2025).

A narrative review of monitoring in female youth athletes examined internal and external load measures together, and drew attention to two points of direct relevance to PE: the validity and practicality of most measures are poorly characterised in female youth populations, and menstrual cycle reporting is a substantive missing element in load monitoring (Temm et al., 2022).

Collegiate women's sport provides a further reference point, in which practice workloads have been characterised with the explicit aim of informing return-to-play decisions (Kupperman et al., 2021). Together these studies indicate that load monitoring is a technically feasible but demographically skewed enterprise.

3.2. Measurement Quality: What Can and Cannot Be Trusted

Because feedback inherits the error of the measurement on which it is based, the validity of consumer devices in school-aged populations is a pedagogical issue, not merely a technical one. The evidence is uneven across metrics. In a study of nineteen adolescents who completed a 24-hour protocol in a metabolic chamber while simultaneously wearing eleven commercially available wrist devices and a research-grade accelerometer, the accuracy of total step counts and 24-hour total energy expenditure differed substantially between devices,
with several consumer devices performing acceptably for steps but poorly for energy expenditure (Hao et al., 2021).

A school-based validation of a consumer device for monitoring children's activity reached similar conclusions (Mooses et al., 2018).

These findings align with the systematic review published in this journal, which reported that step counting in leading consumer devices reached acceptable accuracy, that optical heart rate sensors performed well at rest and at moderate intensity, and that energy expenditure estimation remained inaccurate across essentially all devices (Grzybowska et al., 2026).

Two implications follow. First, intensity is a far safer basis for student-facing feedback than energy expenditure: telling a student that they have burned a particular number of kilocalories is not supportable by current consumer technology, whereas indicating that they are currently in a moderate or vigorous heart rate zone is defensible with caveats.

Second, the appropriateness of a device cannot be inferred from its commercial prominence. The relatively small number of validation studies conducted in school-aged participants, across the range of body compositions and skin tones represented in a PE class, means that teachers adopting devices are frequently extrapolating beyond the evidence.

Feasibility adds a further constraint that is often underestimated. Lessons are short, classes are large, devices must be distributed and retrieved, data must synchronise, and the mismatch between these practical demands and research-grade monitoring has itself been a subject of methodological work.

One line of research attempted to solve this problem by deriving an equation translating step counts into percentage of lesson MVPA, achieving a strong correlation of 0.896 with accelerometer-determined MVPA and a mean absolute difference of about five percentage points, and then embedding that equation in a wireless pedometer system with a smartphone application intended to give teachers feedback during the lesson (Hartwig et al., 2019).

The design logic is instructive: the value of the system lay not in the sophistication of the sensor but in the deliberate engineering of a metric that a teacher could interpret within the time available.

A qualitative evaluation of remote training to develop a school fitness surveillance system similarly identified the interpretability of data for non-specialist staff as a decisive factor in whether a monitoring system became usable (Egan et al., 2023).

3.3. Feedback Design: An Under-Specified Variable

If devices supply the measurement, feedback is the pedagogical act. Yet the feedback literature in this field is considerably less developed than the sensor literature, and the vocabulary is used inconsistently.

The components of feedback that matter for learning are conventionally organised along four dimensions: *modality* (visual, auditory, haptic, verbal), *timing* (concurrent with the movement, immediately after it, or delayed), *content* (knowledge of results, describing the outcome, versus knowledge of performance, describing the movement itself), and *frequency and scheduling* (continuous, reduced, bandwidth or summary feedback).

A scoping review of digital biofeedback systems for targeted exercise found that feedback was mainly visual, concurrent and descriptive, and most often conveyed knowledge of results; only three of the systems reviewed provided a clear rationale for their choice of feedback design, and only four studies evaluated the feedback itself rather than the system as a whole (Brennan et al., 2019).

That finding describes a field that has been built from the technology outwards.

The consequence is a body of evidence in which feedback is treated as a feature of a device rather than as a designed instructional variable.

In the PE-specific literature, this is visible in the most directly relevant systematic review: of 23 included studies, strong evidence supported feedback over no feedback for skill learning, but evidence comparing visual with verbal feedback was limited, and comparisons of informational, praise and corrective feedback were mixed (Zhou et al., 2021).

The review's authors framed the outstanding questions explicitly as questions about feedback elements rather than about devices, which is the correct framing and, as the subsequent sections show, one that has not yet been widely adopted.

3.4. Mechanisms: How Device Feedback Is Proposed to Work

Four mechanisms are invoked, explicitly or implicitly, to explain why device-derived feedback should affect learning. They are not mutually exclusive, and most intervention studies draw on more than one without testing them separately.

Self-regulation. The most frequently cited mechanism is that feedback supports self-monitoring, which in turn supports goal setting and self-regulation of effort.

Qualitative syntheses of wearable use in young people consistently identify self-monitoring, goal setting, feedback and competition as the routes through which devices are perceived to increase motivation (Creaser et al., 2021), and a randomised trial in adolescents embedded an accelerometer-linked online intervention system explicitly around this logic (Guthrie et al., 2015).

The mechanism is plausible and consistent with broader evidence, but it is usually inferred from user accounts rather than tested against a control condition that receives equivalent attention without the feedback.

Basic psychological needs. The second mechanism draws on self-determination theory, in which feedback is theorised to support the needs for competence and autonomy and thereby to shift motivation towards more autonomous forms. The clearest experimental test in a PE context compared forty adolescents who ran for thirty minutes within a regular PE lesson either with or without real-time, individually referenced heart rate feedback.

Participants receiving feedback reported greater enjoyment of running and showed higher physical effort; the authors interpreted the effect in terms of support for autonomy and competence (Stöckel & Grimm, 2021).

Survey evidence is broadly consistent: perceived autonomy support, feedback and course interest have been linked to attachment-related outcomes in PE (Sağın et al., 2025), autonomy-supportive teaching has been associated with more positive emotional perception in PE classes (Leisterer & Paschold, 2022), motivational processes in PE have been linked to objectively measured activity outside school (Kalajas-Tilga et al., 2020),

and objectively measured activity during PE has been found to predict intrinsic motivation independently of academic achievement level (de Bruijn et al., 2023).

The wider self-determination literature in adolescents and young adults provides the conceptual scaffolding for these claims (Kalajas-Tilga et al., 2022; Nurmi et al., 2016; Owen et al., 2013; Sebire et al., 2013; Wang, 2017). It is worth noting that the direction of causality in the survey

studies is genuinely ambiguous: enjoyment may produce effort as readily as feedback produces enjoyment.

Attention and cognitive load. A third mechanism concerns what feedback does to attention. Augmented feedback can direct attention towards relevant movement information, but it can also displace attention from the task itself, and the classical speed–accuracy and impulse-variability principles governing ballistic skill learning describe how task constraints interact with instruction and feedback (Molina et al., 2019).

This mechanism is rarely measured in PE studies, although it is the most plausible explanation for why continuous visual feedback displays sometimes fail to improve retention even when they improve performance in the moment.

Evidence from biofeedback research outside PE is relevant here: visual biofeedback of trunk-sway smoothness has been shown to support motor learning in a unipedal stance task (Cruz-Montecinos et al., 2020), and device-based biofeedback has been shown to alter balance performance with apparent sex differences (Wang et al., 2021a, 2021b).

Auditory and vibrotactile channels have also been tested as alternatives or complements to visual feedback (Casellato et al., 2019; Pitale & Bolte, 2018), and a randomised pilot trial found that exergame training with augmented feedback improved knee joint proprioception in healthy adults (Zhang et al., 2026). These studies demonstrate that feedback channel and content are experimentally tractable variables; they have simply not been systematically varied in PE settings.

Teacher decision-making and assessment. The fourth mechanism is at least as important as the other three and is much less studied as a learning mechanism: device data can change what the teacher does. Formative assessment requires the teacher to know where each student stands relative to a learning goal, and wearable data offer a continuous, individualised basis for that judgement.

The monitoring system described earlier was designed precisely to make lesson-level activity data available to the teacher in a form usable during instruction (Hartwig et al., 2019). Yet this mechanism is almost always evaluated as a feasibility outcome rather than as a mediator of student learning.

3.5. Evidence on Movement Load

The most consistent and best-evidenced outcome of device-supported PE is an increase in in-class physical activity.

The clearest recent demonstration comes from a controlled study in four PE classes at a low-income public school: 55 students aged 11–14 were assigned to two weeks of wearable-supported PE or usual PE, and analyses of the 52 students with complete data showed a significant group-by-time interaction for in-class MVPA favouring the intervention group with a substantial effect size.

Feasibility benchmarks for recruitment, retention, data completeness and technology adherence were all met, and the intervention was delivered within ordinary lessons by existing staff (Ryu et al., 2026).

The design features of this study are worth noting: the wearable was embedded in instruction rather than added to it, the outcome was measured by an independent device rather than the intervention device, and the feasibility benchmarks were specified in advance.

Broader school-based evidence points in the same direction but with more heterogeneity. School physical activity interventions have increased activity during the school day and, in some trials, produced downstream effects on academic outcomes (Cradock et al., 2014; Đurić et al., 2021; Lima et al., 2020). Cluster-randomised work comparing pedagogical models has shown that the pedagogical approach, rather than the presence of technology, shapes the activity accrued (Crotti et al., 2021).

Trials that supplied devices or monitors without redesigning instruction have generally produced smaller and less durable effects (Arlinghaus et al., 2021; Weaver et al., 2018a, 2018c), and the pooled youth evidence remains inconclusive (Au et al., 2024; Grzybowska et al., 2026).

The pattern across these studies supports a specific reading: devices raise activity when they are used to change what happens in the lesson, and much less so when they are used to record what happens in the lesson.

3.6. Evidence on Motor Skill Learning, Motivation and Engagement

The evidence on skill learning is derived mainly from studies of visual and video feedback rather than from wearable sensors proper, but it is directly relevant because the feedback channel is the same.

A quasi-experimental study of 36 students found that digital video feedback produced a substantial improvement in round-off performance in gymnastics, with scores rising from a mean of 1.74 to 3.67 and an effect size of $r = 0.86$ (Fauzi et al., 2026).

A quasi-randomised trial in 73 sixth-grade students compared four conditions across seven table tennis lessons — written instruction sheets, self-recorded video, instructed video delivered through a coaching application, and traditional instruction — and found that all groups

improved, with the video-supported conditions performing at least as well as traditional instruction within a compressed time frame (Feng et al., 2025).

A randomised controlled trial in 56 university beginners compared digital corrective feedback generated by a large language model and embedded within reciprocal teaching with peer feedback alone over a fifteen-session handball course; the design required mandatory manual verification of the automated feedback, a detail that is methodologically important given the error-proneness of automated feedback in motor domains (Rakha, 2026).

A mixed-methods pilot study of an eight-week augmented reality golf programme in 24 undergraduates found a moderate descriptive increase in learning motivation and indications of increased attention, but effects did not survive adjustment for multiple comparisons, which the authors reported candidly (Cheng & Chiu, 2026).

Related work has examined motion decomposition and visualisation in gymnastics education (Yang et al., 2026) and, more broadly, the effects of artificial intelligence applications on motor learning, motivation and engagement (Daly et al., 2026). Peer-mediated feedback without devices has an established evidence base in PE (Whipp et al., 2015), which is a useful reminder that the active ingredient may be the feedback structure rather than the technology.

An eight-week randomised controlled trial in 70 first-year university students integrated smartphone-based kinematic feedback into an interdisciplinary curriculum and reported gains in kinematic performance, blinded technique ratings and autonomous motivation (Zhang, 2026).

Evidence on motivation and engagement at scale is more equivocal. The largest relevant study in a university setting surveyed 1,182 students across four Chinese universities and combined structural equation modelling with interviews.

Use of wearable-derived dashboards and automated alerts was associated with perceived smart teaching quality and with personalised feedback, which were in turn associated with physical literacy and learning engagement; the direct path from analytics use to physical literacy was negligible. In other words, the effect of the technology was fully mediated by pedagogical variables (Chen et al., 2026).

A similar pattern of mediation by motivational and social processes appears in cross-sectional work on wearable equipment and exercise persistence (Han et al., 2025), and the studies discussed earlier on real-time heart rate feedback (Stöckel & Grimm, 2021) point in the same direction. Studies of gamified and television-game-based PE have reported motivation gains but usually over short periods and with limited follow-up (Ferriz-Valero et al., 2020).

Conversely, the study that produced the clearest MVPA gain found no significant change in psychosocial beliefs (Ryu et al., 2026), and pooled youth trials have not shown significant effects on activity (Au et al., 2024).

The most defensible summary is therefore asymmetric. Device-supported feedback in PE reliably changes what students do within lessons. Whether it changes what students believe about themselves as movers, or what they retain after the devices are removed, is not yet established.

3.7. Equity: Who Is Represented, and Who Benefits

The demographic skew of the wearable literature is one of its most consistent findings. In the two large reviews of wearable workload monitoring in team sport, male athletes accounted for 81% of studies, elite or professional athletes for 74%, and soccer, rugby and Australian football for two thirds of the evidence base (Benson et al., 2020; Gómez-Carmona et al., 2020); accelerometry-based external load research shows the same pattern (Gómez-Carmona et al., 2020).

Female youth populations are explicitly identified as under-characterised with respect to the validity and practicality of load measures, and menstrual cycle data are routinely absent (Temm et al., 2022).

In PE research specifically, three equity-relevant strands are visible. The first concerns girls and young women: process evaluations of programmes linking PE with community sport have documented the structural and social barriers that shape girls' participation (Casey et al., 2014), and device-based studies have reported sex differences in response to feedback (Wang et al., 2021b).

The second concerns socioeconomic disadvantage: the study that demonstrated the clearest MVPA effect was deliberately conducted in a low-income school and framed as an equity intervention (Ryu et al., 2026), while teacher-reported barriers to activity among inactive adolescents cluster in physical opportunity and reflective motivation domains, both of which are socially patterned (Moore et al., 2023).

The third concerns students with disabilities and those marginalised in sport: inclusive PE approaches have been developed specifically for sport-marginalised students (Kwon et al., 2025), and faculty perspectives on adapted PE highlight persistent gaps between policy and delivery (Park, 2023).

Two further equity considerations are specific to wearables. Device-based measurement may render some students' movement invisible when the algorithms underpinning it have been

validated in populations unlike them, and the visibility that devices create may be experienced differently by students who are self-conscious about their bodies, their skill level or their socioeconomic circumstances.

Neither issue is well addressed in the current literature.

3.8. Teachers, Data Literacy and Workload

Devices do not interpret themselves. The realisation of any pedagogical benefit depends on teachers who can read, question and act on data within a lesson that lasts less than an hour.

Qualitative work with 156 PE teachers identified 21 barriers to physical activity among inactive adolescents, distributed across capability, opportunity and motivation domains, and examined the acceptability of a further digital exercise intervention against that backdrop (Moore et al., 2023).

Students' own perceptions of technology integration in PE have been examined in studies of heart-rate-monitor-based units, where students valued the visibility of effort but also reported that the technology changed the social character of the lesson (Marttinen et al., 2019); broader cross-sectional work on students' acceptance of digital media in PE reports generally positive but conditional attitudes (Mackenbrock & Kleinert, 2026).

On the teacher side, professional development appears to be a meaningful lever: technology-focused training workshops have been associated with PE teachers' job satisfaction, commitment and self-determined motivation (Tian et al., 2026), and participatory, competency-building approaches have increased teachers' physical activity promotion and students' activity in pilot work (Weaver et al., 2018b).

Pre-service teachers' engagement with digital environments has been examined in the Chinese context, where social media forms a substantial part of the professional information environment (Xu et al., 2023).

Two further points deserve emphasis. First, feedback is relational as well as informational: students' experience of being seen and recognised by their PE teacher is itself associated with motivational outcomes (Andresen et al., 2023), and a device that displaces rather than supports that relationship would be a poor trade. Second, data literacy is not the same as technical literacy.

Interpreting a heart rate trace, judging whether an anomalous value reflects measurement error or genuine effort, and deciding whether to intervene or to leave the student alone are professional judgements, and the studies reviewed above suggest that the field has invested much more in generating data than in preparing teachers to make those judgements.

3.9. Ethical, Privacy and Practical Constraints

Wearable measurement in schools produces identifiable data about minors, often continuously, frequently on commercial platforms, and sometimes under conditions of limited consent. This is not a peripheral concern; it is a design constraint on what can legitimately be done.

Practical and ethical guidance for schools adopting digital approaches to physical literacy has been developed, and it identifies consent, data governance, the risk of surveillance-like monitoring and the differential vulnerability of students as central issues (Bopp & Stellefson, 2020).

A qualitative evaluation of the implementation of a school fitness surveillance system provides a concrete illustration of how these issues surface in practice, including questions of who owns the data, who sees it, and what happens when a value is alarming (Egan et al., 2023).

Student-level survey evidence supports the same conclusion from the user side: privacy concerns entered the acceptance model for sports smart wearables as a significant predictor rather than as a marginal consideration (Wu et al., 2026). The pooled evidence on adherence and dropout in youth wearable studies also points to a practical dimension of the same problem, since devices that are abandoned produce neither data nor learning (Creaser et al., 2021; Ridgers et al., 2016; Smith et al., 2023).

Recent Chinese policy and research interest in data-driven governance of student physical health (Deng et al., 2022) and in medical-health data-driven PE schemes (Yue, 2022) makes these questions urgent rather than hypothetical.

A defensible position for practice is that the minimum data necessary should be collected, that processing should occur as close to the point of use as possible, that students should be able to see and understand their own data, and that devices should be switched off by default when they are not serving a stated learning purpose.

4. Discussion

The literature reviewed here supports a single organising proposition: the educational value of wearables in PE lies not in the measurement but in the feedback loop that the measurement closes. Devices change what is visible to students and to teachers; feedback is the mechanism through which visibility becomes learning.

When that loop is closed deliberately — as in the lesson-level MVPA monitoring system designed around a metric a teacher could act on (Hartwig et al., 2019), or in the wearable-supported PE programme that produced a substantial MVPA effect within ordinary lessons in a low-income school (Ryu et al., 2026) — outcomes improve. When devices are added to

lessons without redesigning the feedback structure, gains are smaller, less durable and more dependent on novelty.

This framing has four consequences for practice.

First, **choose metrics for interpretability rather than precision**. Step counts and heart rate bands are adequately measured by consumer devices and are directly meaningful to students; energy expenditure is not adequately measured and is not meaningful in the way students assume (Grzybowska et al., 2026; Hao et al., 2021). A teacher who makes a feedback decision is, whether they intend it or not, making a claim about measurement validity.

Second, **design the feedback, not the dashboard**. The dimensions that matter — modality, timing, content, frequency — are the same dimensions that the motor learning literature has studied for decades, and they are cheaper to vary than devices are to buy (Brennan et al., 2019; Zhou et al., 2021). The most common failure mode observed in this literature is a system in which the teacher has chosen an elaborate feedback mode without a rationale for it.

Third, **measure learning, not just activity**. Increasing in-class MVPA is a legitimate and achievable goal, and it is the best-supported outcome of device-supported PE. It is not equivalent to learning. Studies that report only device-derived activity, particularly when measured by the same device that delivers the intervention, may overstate the pedagogical value of the technology.

Fourth, **plan for equity and privacy before implementation**. The current evidence base is dominated by male, able-bodied and comparatively advantaged populations (Benson et al., 2020; Gómez-Carmona et al., 2020; Temm et al., 2022), which means that the confidence with which any conclusion can be extended to, for example, a first-year university women's basketball option course is limited.

Constructing the intervention so that it is tested in the population in which it will be used is both a scientific and an ethical improvement.

Several specific research priorities follow. Studies should treat feedback design as the independent variable rather than as a property of a device; report measurement validity in the specific population and setting of use; include retention or transfer tests rather than only immediate performance;

measure the teacher-mediated pathway explicitly, since the largest university study found that the technology effect was fully mediated by pedagogical variables (Chen et al., 2026); test in under-represented populations, including female students and students in non-elite university

courses; and report implementation data with sufficient granularity that feasibility, rather than efficacy alone, can be judged (Ryu et al., 2026).

Finally, the literature contains an implicit assumption that deserves to be made explicit. Many interventions assume that students will find their own data motivating.

The evidence reviewed here suggests that this assumption holds conditionally: it holds when data are legible, when they support rather than undermine competence, when there is a teacher or peer structure that gives the data meaning, and when the measurement does not become a source of anxiety or social comparison.

Where those conditions are met, the effects observed are among the largest in this literature (Ryu et al., 2026; Stöckel & Grimm, 2021); where they are not, the device is an expensive stopwatch.

5. Limitations

This review has several limitations. It is narrative rather than systematic; consequently it does not provide a complete enumeration of the literature, and the selection and weighting of sources involved judgement. No formal risk-of-bias appraisal was performed, although study design and population are stated at each citation so that the reader can calibrate the strength of each claim.

Because the review deliberately spans measurement science, motor learning and motivational theory, the treatment of each individual area is necessarily less deep than a single-domain review would be.

The evidence base itself is uneven in ways that limit the conclusions: several of the most directly relevant studies are small, of short duration, and conducted in single institutions; the wearable literature is demographically skewed towards male and elite athletes; the studies most directly concerning PE are predominantly from a small number of national contexts;

and the studies concerning digital skill feedback rely on paradigms — video, augmented reality, automated feedback — that overlap with, but are not identical to, wearable sensor feedback.

Finally, the field is moving quickly, and both device capability and the research literature are likely to change substantially in the near term.

6. Conclusions

Wearable device feedback in physical education is best understood as a pedagogical intervention that depends on measurement, rather than as a measurement technology with pedagogical side effects.

Devices in current use measure steps, heart rate and, with increasing confidence, aspects of movement quality; they do not measure energy expenditure reliably, and their validity in the specific populations found in a PE class is often unverified. Feedback derived from these devices is predominantly visual, concurrent and descriptive, and is generally not informed by an explicit theory of learning.

The clearest demonstrated benefit of device-supported PE is a short-term increase in in-class moderate-to-vigorous physical activity, particularly when devices are embedded in redesigned instruction. Effects on motivation, psychosocial beliefs and skill retention are plausible, mechanistically coherent and, at present, inconsistent.

Because the largest studies indicate that the effects of the technology are mediated by pedagogical variables such as feedback quality and perceived teaching quality, the productive question for both research and practice is not which device to buy, but what feedback the device should generate, for whom, and to what end.

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In preparing this work, the authors used an AI-assisted writing tool (e.g., Claude) for the purpose of improving the language and readability of the text. After using this tool, the authors reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

Supplementary Materials

Not applicable. This review has no supplementary material.

Author Contributions

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Conflicts of Interest

The authors declare no conflicts of interest.

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