

Run Like a Fish: Published Literature Review

1. Purpose

I used this review to answer three questions before moving further into prototypes and participant studies:

1. Have published haptic systems already addressed running guidance for blind and visually impaired athletes? As the search developed, this question became more specific. The issue was no longer whether haptics have ever been used with a blind runner, but which exact combination of cue, body location, participant population, and outcome measures still appears untested.
2. Are there existing published and documented findings that can be used in my planned testing on user perception of haptic feedback?
3. Does the literature give enough support for the two biomimetic systems that I have previously identified to make them worth testing? For context the first system is **distributed drift feedback**, inspired by the lateral line of a fish, where a haptic belt would provide left or right correction as a runner begins to move off course. The second is an **accelerating approach cue**, inspired by ideas from bat echolocation and time-to-contact, where vibration pulses would become faster as the runner gets closer to a turn.

2. Search Method

Review type and scope

To answer the three questions above, I conducted a **targeted scoping search**, not a formal systematic review. I looked for three main types of evidence: (1) published or publicly documented haptic systems for navigation or guidance during walking or running; (2) published findings on how people perceive vibrotactile feedback on the torso, especially while moving; and (3) research that could support or challenge the two proposed biomimetic signal designs.

I used the first group of sources to determine what had already been done and where a research gap might remain. I used the second and third groups to guide a potential prototype, planned perception testing, and the design of later experiments.

Search platform and dates

I used Google Scholar as the main platform for finding publications. I conducted searches from **July 15 through August 31, 2026**. I began with broad, exploratory searches, then narrowed them using author names, paper titles, named systems, reference lists, and Google Scholar's *Cited by* function to verify records and fill in gaps. I then checked candidate sources against original papers, publisher pages, conference proceedings, DOI records, government reports, and official project pages. I used publisher and repository sites mainly to retrieve and verify sources rather than as separate databases.

Search strategy

I ran the queries as free-text searches, without database field tags. The broad searches combined a population, an activity, a feedback method, and a guidance function. Following are the types of search queries I used:

- **Systems and near-misses:** haptic guidance visually impaired runners running pace; haptic navigation blind athletes track lane keeping; wearable haptic guidance skin stretch waist visually impaired runners; blind athlete guidance device.
- **Torso perception:** vibrotactile localization abdomen tactor spacing accuracy; vibrotactile perception walking running treadmill accuracy; tactor localization soldier moving; vibrotactile stimulus duration threshold pulse.
- **Hypotheses and workload:** vibrotactile target acquisition accelerating pulse rate; looming vibrotactile collision warning; vibration rhythm distance navigation; Wizard of Oz haptic navigation visually impaired track; haptic versus audio navigation NASA-TLX workload.

After the broad search, I ran more targeted searches for known authors, titles, and systems, including BLINDTRACK, Pieralisi, Kayhan and Samur, Liao, TrackAid-DT, RunPacer, and the Brazilian trajectory-correction projects. I also used older wording such as *blind athlete guidance device* because early systems did not always use the modern term *vibrotactile navigation*.

Eligibility and evidence classification

For earlier systems, I kept work using any haptic body location and at any stage of development, including technical prototypes without a full user trial. I then classified each source by participant population, activity and speed, body location, sensing method, whether the guidance was reactive or anticipatory, whether a human operator was involved, and which outcomes were measured. Studies with blind or visually impaired participants were kept separate from studies with blindfolded sighted participants; the second group can show technical feasibility, but it does not count as end-user validation.

For torso-perception benchmarks, the vibration had to be delivered on the waist, abdomen, back, or broader torso. For signal-coding evidence, I allowed other body locations when the experiment directly tested cadence, intensity, looming, or time-to-contact. Audio-only systems and obstacle-warning devices without navigation or lane-keeping were excluded. Commercial products and press reports were kept only as clearly labeled context. I used English-language sources and did not set a date limit.

Citation tracing, records, and limitations

I checked the reference lists of the core belt, running, and perception studies, as well as later papers that cited them. I used the 2024 IEEE review *Hands-Free Haptic Navigation Devices for Actual Walking* as a secondary index, but whenever possible, I verified claims against the original sources. I also conducted a final gap-filling search for recent haptics and accessibility research and official project records.

I did not log the earliest exploratory searches as I conducted them, so I cannot confidently reconstruct the exact number of results I reviewed or duplicates I removed. For that reason, this review does not claim a precise total number of screened records. The revised annotated bibliography includes **50 separate works or public records** that I used as research evidence or clearly labeled context.

Several limitations remain. I conducted the review on my own, Google Scholar rankings can change over time, and I only reviewed English-language material. I also did not use a formal risk-of-bias tool or conduct a patent search, and Google Scholar may under-index some older conference papers and project reports. Because of these limits, I restrict my conclusions to the sources identified through the documented search as of **August 31, 2026**, rather than claiming to cover all unpublished work or establish legal patent novelty.

3. The Gap: What has been done, and what remains

I originally thought the research gap I was pursuing was that haptic guidance had not yet been meaningfully used to help blind or visually impaired people run independently. The literature showed that this was not true. Haptic guidance at running pace, vibration-based trajectory correction with visually impaired athletes, torso-mounted displays, and even attempts at independent track running already have published or publicly documented examples. My project can still make a useful contribution, but that contribution has to come from the exact cue comparison and evaluation, not simply from putting haptics on a blind runner.

- **BLINDTRACK (2014-2015) - closest system-level predecessor.** This European project combined real-time track localization, trajectory prediction, collision handling, and an eight-motor tactile belt designed to let blind runners use a 400 m track without a guide. The official final report describes a field trial with six visually impaired volunteers. The available project and conference reports explain the system architecture, but they do not provide the same controlled comparison of anticipatory cue designs, path outcomes, and workload planned here.
- **Pieralisi et al. (2015, 2017) - actual blind athlete at running pace.** Their infrastructure-based electromagnetic system used a waist sensor and vibrators on the upper arms to warn when the athlete approached track boundaries. In the 2017 field test, one blind athlete completed three 400 m running laps at mean speeds of about 2.22-2.63 m/s. This is real running evidence, not just fast walking, but the cues were reactive boundary warnings and the system depended on wires installed around the track.
- **Brazilian trajectory-correction systems - visually impaired sprinters.** Cordovil Júnior and colleagues reported a vibration-based trajectory-monitoring system tested with eight visually impaired athletes during training and 100 m sprint tasks. Machado and Carvalho's Pro-Athlete system used remotely triggered belt and bracelet cues with five visually impaired track athletes in simulated races. Together, these studies show that haptic correction with actual visually impaired runners is not new, although the systems were reactive or operator-dependent and the published outcome data are limited.
- **Kayhan and Samur (2022) - closest waist-worn running experiment with a fully described participant test.** Their system converted camera-derived steering angles into **skin stretch**, not vibration, around the waist. Four participants - one visually impaired and three blindfolded - completed a 400 m trial. The system produced fewer warnings and lane violations than verbal guidance, and the visually impaired participant reached about 2.1 m/s. The results are promising, but this was still a small reactive pilot with one end user and no workload or anticipatory-turn comparison.
- **Mancini et al. (2018) and TrackAid-DT (2026) - portable camera sensing with glove feedback.** These systems used a chest camera and vibrotactile gloves to support running on marked lanes. TrackAid-DT's end-to-end feasibility test involved two blindfolded sighted participants completing twenty 400 m laps at a mean speed of 2.69 m/s. Speed was the main reported measure of human feasibility; the study did not report quantitative path error, workload, obstacle performance, or testing with visually impaired athletes.
- **Liao et al. (2021, 2023) - lower-leg haptics and route following.** A drone estimated the desired running direction and sent that information through a six-vibrator display on the lower leg. The 2023 study included both treadmill direction recognition and an outdoor 48 m route-following experiment with seven blindfolded sighted adults. With the system, participants stayed inside the narrow track about 81% of the time. This is a direct running-guidance

example, but it did not test visually impaired runners, torso delivery, turns, or anticipatory approach information.

- **Hirano et al. (2019) and RunPacer (Yu et al., 2025) - running haptics for pace synchronization.** Both use vibration during running, but the human guide still handles navigation. RunPacer is a peer-reviewed ASSETS poster with an arXiv version, not just an unreviewed preprint; its five pairs used blindfolded sighted runners rather than visually impaired runners.
- **Wayband - commercial context only.** A wrist-worn haptic system was publicly demonstrated during an attempted unassisted New York City Marathon run, but press coverage is not a controlled peer-reviewed evaluation and does not count as evidence for the novelty conclusion.

Based on searches completed through **August 31, 2026**, I did not find a peer-reviewed controlled experiment that compared an **anticipatory, accelerating turn cue** with a simpler cue on a **torso-mounted vibrotactile display** during running by **visually impaired participants**, while also measuring **navigation performance** and **human-factors outcomes** such as workload or usability. This narrower gap definition is a novelty claim I can defend. The project is not the first haptic running system, the first vibrating belt, the first independent-track concept, or the first reactive trajectory-correction system. Its potential contribution is the controlled test of a specific anticipatory signal and how that signal performs under exertion with the intended users.

4. What the field already knows

Narrowing the research gap did more than change the project's novelty claim. It also showed which questions previous research has already answered well enough to guide the design. Instead of testing every basic assumption from scratch, I can use published findings to eliminate some unnecessary testing, choose better starting points for the prototype, and focus participant testing on the questions that remain unresolved. This section looks at what the field already knows and how those findings can directly shape the next stages of the project.

Navigation belts and signal codes

van Erp, van Veen, Jansen, and Dobbins (2005) is still the most directly useful belt paper for the coding question. Their eight-tactor waist display showed that direction could be mapped to vibration location with very little training. In their setup, adding rhythm-coded distance did not improve performance compared with providing no distance information. The result supports location as a strong way to communicate direction and warns against treating pulse rate as a continuously updated distance dial.

Flores et al. (2015) provides a strong walking example with ten blind participants. Vibrotactile guidance improved path accuracy compared with audio, but participants moved more slowly. That tradeoff between speed and accuracy also appears in nearby areas of the literature and matters even more for a running system.

Brandebusemeyer et al. (2021) followed eleven blind users who wore a continuously signaling feelSpace belt for seven weeks. This small long-term study suggests that an ongoing torso signal can become more comfortable and may help confidence, but it does not show that every user will accept continuous feedback or that the same result will carry over to running.

Distance and approach coding produce mixed results. Pielot's Tactile Compass, NaviRadar, and Schätzle and Weber show that pauses, intensity changes, and near-target changes can work in some tasks, while van Erp and Straub found no useful benefit from the distance codes they tested. Oron-Gilad et al. found that changing burst rate near a target improved target acquisition, and Meng

et al. found faster braking responses to a dynamic looming tactile warning. The main lesson is not that rhythm always works or always fails; it depends on what the signal is meant to communicate and when the user needs to act.

Torso perception: published benchmarks

Cholewiak, Brill, and Schwab (2004) found better absolute localization near “anatomical anchors” such as the navel and spine and weaker performance at the sides. In the arrangements they tested, six- and eight-position displays produced roughly 92-97% accuracy, while a denser twelve-position layout was about 74%. This supports starting with six to eight well-spaced positions, but it does not mean that every belt should stop at eight factors.

Jóhannesson et al. (2017) looked at a different ability: deciding whether a second vibration moved left or right compared with the first. Performance stayed above chance at separations as small as 13 mm. A drift cue may depend more on this kind of relative change than on identifying one exact motor, so these results do not actually conflict with the absolute-localization findings.

Motion reduces performance. Demircan et al. found that overall cue-identification accuracy dropped by about 9% from walking to running, with a much smaller decline for single-motor cues than for multi-motor combinations. Staggered patterns also worked better than continuous patterns. Redden et al. separately found lower torso-localization accuracy on a moving soldier course than in static conditions. These results are useful starting points, but neither study tested the exact motors, attachment pressure, clothing, or waist layout planned for my device.

Frequency and duration values are starting points, not device specifications. Research on Pacinian sensitivity and TSAS suggests roughly 200-250 hertz(Hz) is a reasonable range for strong cues during motion, but coin motors do not necessarily produce their rated response at the skin. Wang et al. found a practical localization/comfort range around 80-320 milliseconds (ms) in one torso-belt setup. Remache-Vinueza et al.'s approximately 30 ms value answers a different question - when a stimulus begins to feel like vibration rather than a brief pulse - and is not a universal detection threshold.

Adjacent zero-visibility domains

Research from aviation, firefighting, diving, and soldier navigation gives useful but indirect evidence. TSAS work suggests torso cues can still work during demanding, vibration-heavy tasks. Slater et al. found that a waist display improved firefighter movement and situation awareness in zero visibility. Camacho et al. found better navigation accuracy, but sometimes slower completion, with blind participants and blacked-out divers. Eriksson et al. reported similar navigation precision for visual, tactile, and 3D-audio displays, with less attentional interference from tactile guidance than 3D audio. These studies support feasibility and help identify useful outcomes, but they do not prove the same effects will occur while running.

5. The two biomimetic hypotheses against the evidence

The next question is whether the two biomimetic signal designs are supported strongly enough by existing research to justify testing them. The fish lateral line and bat echolocation provided the original inspiration, but the animal comparisons are not evidence that the same ideas will work on human skin while running. In this section, I look at the published evidence for and against each idea, identify the weaknesses or risks that need to be considered, and use those findings to decide how each signal should be tested.

Hypothesis 1 - Distributed gradient sensing (fish lateral line)

The claim: a ring of tactors stays quiet while the runner is centered and gives progressively stronger left/right correction as drift develops. Before testing, *graded* needs a precise meaning: it could mean moving the active location, increasing intensity, increasing pulse rate, or turning on more motors. Those are different signals and should not be mixed together in one condition.

Evidence for:

- Torso displays can communicate direction with little training in walking, aviation, firefighter, and blind-navigation studies.
- A small seven-week feelSpace study suggests that a continuous torso signal can become easier to tolerate and may support confidence.
- People can notice relative left/right changes at much smaller separations than they can reliably identify an exact motor, which is encouraging for correction rather than labeling.
- Pieralisi and Durá-Gil independently explored more continuous correction patterns, so there is already a published technical basis for asking this design question.

Evidence against:

- Absolute localization gets worse when positions are crowded together, especially at the sides of the torso.
- Running hurts performance on multi-motor and continuous patterns more than on simple or staggered cues.
- An always-on signal could lead to adaptation, annoyance, or unnecessary workload even if people can get used to wearing a belt over time.

Resolution: the literature makes the many-motor, always-on version hard to justify. A mostly silent design still seems worth testing: no cue while the runner is centered, followed by one clearly defined graded correction as error grows.

Hypothesis 2 - Accelerating approach cue (bat echolocation / tau)

The claim: pulses start farther apart as a turn approaches and then get faster as the available time to act gets shorter. The cue should be called *tau-shaped* only if its timing is updated using estimated time-to-turn. A fixed pulse schedule triggered at a fixed distance is still an accelerating warning, but it is not automatically a tau signal because runners approach at different speeds.

Evidence for:

- Oron-Gilad et al. found better target-acquisition performance when burst rate changed as the user got closer to the target.
- Meng et al. and Gray found faster responses to dynamic looming warnings than to more static warnings in driving tasks.
- Bernard et al.'s rhythmic-gradient experiment found similar threshold patterns for haptic and auditory rhythm, which supports pulse rate as a reasonable coding dimension in that task.

- Lee's tau theory gives a logical reason to connect the cue to time-to-action rather than simply to the number of meters remaining.

Evidence against:

- van Erp found no benefit when rhythm was used as a continuous distance code on a navigation belt.
- More dynamic features did not always help; Meng et al. found no extra benefit from adding a separate looming-intensity profile to a cue that was already dynamic.
- An accelerating cue could look better simply because it starts earlier or gives more total vibration unless the control conditions are carefully matched.

Resolution: the experiment should separate an approaching-event warning from a distance meter. It should compare at least three conditions: (1) accelerating cadence, (2) fixed-rate cadence with the same onset and about the same total vibration exposure, and (3) a single cue at or near the turn. The literature does not tell us which will work best during running; finding that out is the point of the controlled comparison.

How the evidence should guide future testing

The literature does not tell me whether either hypothesis will work, but it does help me design a fair test of each one. For the drift cue, I need to test one clearly defined type of feedback rather than combining changes in location, intensity, and number of motors. For the approach cue, I need to compare the accelerating signal with simpler cues that begin at the same time and provide about the same amount of vibration. That way, if the accelerating cue performs better, I can be more confident that the acceleration itself made the difference, rather than simply giving the runner more warning

6. Using the literature to design future testing

My current research plan calls for a series of controlled perception tests before moving to a full running-navigation experiment. For these tests, I plan to build a simple wearable haptic device with vibration motors positioned around the torso. This early version will allow me to test the signals themselves before developing the more complete navigation prototype. I will use these tests to determine how well users can recognize and distinguish different haptic cues. Participants will first complete a short seated or standing baseline, then repeat the same cue-recognition tasks during walking or controlled exertion. This will show how factors such as movement, motor placement, clothing, and attachment pressure affect how clearly the cues can be perceived. The published literature gives me useful starting points for these tests, but testing is needed to confirm which settings and cue patterns actually work with the planned device and under the conditions of this project.

Parameter	Published finding	Source	Design consequence
Absolute torso localization	About 92-97% with 6-8 positions; about 74% with 12 in the tested layouts	Cholewiak 2004	Start with 6-8 well-spaced positions and use midline anchors. Treat this as a study-specific prior, not a universal maximum.
Relative left/right discrimination	Participants could distinguish the direction of a relative vibration shift at separations as small as 13 mm at above-chance levels	Jóhannesson 2017	Relative drift-change tasks may support tighter spacing than absolute motor identification.
Walking-to-running perception loss	Cue-identification accuracy decreased by about 9% overall from walking to running; the decrease was much smaller for single-motor cues and larger for multi-motor cues.	Demircan 2020	Keep simultaneous motor count low and test the actual cue set under exertion.
Activation pattern during motion	Staggered patterns outperformed continuous patterns in the tested walking/running task	Demircan 2020	Include sequential or intermittent patterns rather than assuming sustained vibration is best.
Localization during a moving soldier task	Localization accuracy dropped during a moving soldier course; the best tested actuator condition produced about 79% accuracy.	Redden 2006	Expect movement-related loss and compare body locations using the actual hardware.
Starting frequency region	Roughly 200–250 Hz is a reasonable starting region for strong Pacinian-mediated vibration cues	TSAS and perception literature	Use this as a starting point when choosing hardware, then verify the vibration actually delivered through the belt, clothing, and movement.
Localization/comfort duration	Roughly 80-320 ms in one coin-motor torso study	Wang 2024	Use as an initial test range, not a final specification; motor spin-up and attachment change the physical pulse.
Pulse-to-vibration transition	Around 30 ms across the tested frequencies	Remache-Vinueza 2025	This describes how the stimulus is experienced, not a universal detection threshold or a torso-localization limit.

Two distinctions are especially important when using these findings to plan future testing. First, identifying one exact motor is different from noticing whether a vibration has shifted left or right. A drift cue may be able to use that second ability without requiring the wearer to identify a specific motor. Second, the published results should be treated as useful starting points, not as pass/fail standards for this project.

Testing should therefore confirm these findings using the actual hardware and conditions planned for this project. A short seated or standing baseline could first measure how well participants recognize the cues under controlled conditions. The same cues could then be tested during walking or controlled exertion to see how movement affects perception. Because factors such as motor type, placement, clothing, and attachment pressure may differ from earlier studies, the results from the literature cannot simply be assumed to apply to this device. If the initial participant group is small, the testing should be treated as an exploratory pilot, with cue-identification accuracy as the main measure and response time and individual participant results providing additional information.

7. Other research that helps shape future testing

Some of the literature does not directly address the two main haptic signals, but it still provides useful guidance for the next stages of the project. Research on veering suggests useful ways to measure path control, Wizard-of-Oz studies show how a human operator can be used during early testing, workload studies show why cognitive effort may need to be measured, and prior work with different participant groups helps clarify when blindfolded sighted users are useful and when testing with blind or visually impaired runners is necessary. These findings do not determine the final study design, but they provide evidence that can guide it.

Veering: the problem is measured, but the benchmark must be stated correctly

Kallie et al. found measurable veering from accumulated step-direction errors in blind and blindfolded walkers. The paper reported mean unsigned **lateral deviations of about 0.45-1.74 m after 9.14 m of forward travel**; these are distances, not angles. This shows why an external reference matters but should not set a running target without a path model. For later testing, use lateral root-mean-square error, maximum lateral deviation, lane departures, and successful-turn percentage. Souman et al.'s outdoor traces show the same problem: without a stable reference, people can curve off course.

Wizard-of-Oz: a legitimate method with one extra measurement

Rector et al. used human-triggered aural and haptic cues with visually impaired participants on a track, while Poláček et al. used a wizard-plus-evaluator design before a navigation system was complete. This suggests that a trained operator could be used in later testing to separate signal design from sensing and route planning. If that approach is used, every cue should be time-stamped with the intended trigger point, runner position and speed, missed cues, and operator delay. That separates misunderstood cues from late ones.

Workload: promising, but not free

Several studies suggest tactile guidance can leave the auditory channel free and sometimes reduce workload. Kerdegari et al. reported lower NASA-TLX scores and route deviation with haptic than audio guidance; Eriksson et al. found higher workload for 3D audio than tactile waypoint guidance. But Sarfraz et al. found that adding redundant tactile information to audio increased workload. Keep the cue vocabulary small and give touch a clear job; another channel is not automatically free.

Participant population: feasibility is not the same as end-user evidence

Blindfolded sighted participants help debug hardware, compare signals, and find obvious safety problems, but they do not replace blind or visually impaired runners, whose experience and movement strategies may differ. Report the groups separately, and base final usability or independence claims on the intended users.

8. Conclusion: What the review changes

This review changed the project in an important way. I began with a broad question about whether haptics could be used to guide blind or visually impaired runners. The research showed that several systems have already explored that idea, so the real research gap is much narrower. The opportunity is not simply to build another haptic running system, but to test specific signal designs that have not yet been compared under the same conditions with the intended users.

The literature also gives me a stronger starting point for the next stages of the project. Existing research can guide choices about haptic perception, motor spacing, vibration patterns, movement, workload, participant groups, and how future experiments should be controlled. It does not tell me exactly what the final system or study should look like, but it helps eliminate questions that have already been answered and focuses future testing on the ones that remain. The next step is to use these findings to develop and test the prototype, then design later experiments around the questions the literature has not resolved.