

MOTOR SKILL COMPOSITION AND THE COMPARABILITY OF SPORTING RECORDS

Shin Min Kang

Seoul National University, Seoul, Republic of Korea

Received: 16/02/2026 Revised: 27/4/2026 Accepted: 03/6/2026 Published: 20/06/2026

Correspondence: smkang@snu.ac.kr

ABSTRACT

Finishing times combine the motor skills required by a particular contest. Changes in equipment, course geometry and resistance can therefore alter the meaning of a comparison between athletes. Completion capability was defined as expected elapsed time conditional on physiological preparedness, movement skill, an action policy and task conditions. Order-preserving transformations, differential time effects and uncertainty intervals were examined mathematically. Official timing and sectional values for the 2018 men's 1500 m short-course final supplied the competition analysis. English-language addressed footwear energetics, swimming, wind and record probability. A strictly increasing transformation exists on attained expected times precisely when all pairwise orders and ties are preserved. Prediction beyond those attained values requires independent calibration. A time-effect difference larger than the preceding performance margin reverses the ordering; interval subtraction determines whether either ordering is supported. Gregorio Paltrinieri's 4.71 s free-swimming advantage over Mykhailo Romanchuk was outweighed by a 5.18 s turn disadvantage and a calculated 0.26 s start difference, producing a 0.73 s finish deficit. Reweighting the completed turn sections changes the arithmetic ordering at approximately 0.859 of their full weight, without predicting another course. An athlete comparison requires a named completion task, specified movement policy, validated adjustment and explicit uncertainty.

Keywords: kinesiology; sporting records; swimming turns; motor skill; completion time; athlete comparison

INTRODUCTION

On 16 December 2018, Mykhailo Romanchuk won the men's 1500 m short-course final in Hangzhou in 14:09.14. Gregorio Paltrinieri finished second in 14:09.87 (OMEGA, 2018). Paltrinieri nevertheless accumulated 4.71 s less time in the free-swimming sections (Polach et al., 2021). The finish order and the free-swimming order answered different questions: one ranked completion of the full course, while the other ranked selected sections between the start and turns. The result directs attention to the motor accomplishments included in a sporting number.

A completion time combines athlete preparation with the actions and physical conditions of the event. Wall push-offs, footwear, drag and timing procedures enter that relationship. A faster mark may establish a superior completed achievement while leaving superiority under different conditions undetermined. Historical comparisons add this difficulty to ordinary trial variation because the athletes can have competed under different task specifications.

Bordner distinguishes judgments of sporting rank from all-things-considered judgments of athletic quality (Bordner, 2016). Completion time is a more restricted quantity: it measures elapsed duration for a specified achievement. It does not separately identify physiological capacity, technical skill or overall athletic merit. In kinesiology, interpretation consequently requires attention to the movement demands that connect those capacities to the observed time.

Equipment legality addresses another question. Dyer examines footwear acceptability through several sporting concerns, including historical comparison (Dyer, 2020). Lopez Frias examines the values underlying claims about naturalness and performance enhancement (Lopez Frias, 2019). Neither legal recognition nor an appeal to natural movement supplies an

individual time correction. O'Connor and Vozenilek's examination of leading swimming performances around swimsuit regulation similarly concerns changes in competitive performance across years (O'Connor and Vozenilek, 2011); that association does not isolate a personal equipment effect for each swimmer.

The question examined here is the transport of an athlete ordering between completion tasks. Expected elapsed time is defined first. The mathematical analysis then establishes the requirements for ordinal correspondence, the exact condition for reversal under differential task effects, and an interval decision rule. The Hangzhou final provides a numerical demonstration of the consequences of changing which movement sections enter the comparison. Record probability identifies a further limitation: additional attempts can lower the best observed time even when the underlying distribution is unchanged. These deductions apply to running and swimming completion tasks; they do not supply a ranking across different sports.

MATERIALS AND METHODS

MATHEMATICAL ANALYSIS AND LITERATURE SELECTION

The calculations combine task definitions, an order-preservation proof, interval arithmetic and the decomposition of one championship finish margin. Competition times enter as observations with identified citations. No athletes were recruited or tested, and no repeated-performance distribution was estimated. The algebra establishes conditional relationships between defined quantities rather than an estimate of how frequently equipment or course changes reverse athlete rankings.

Literature searches took place on 11 October 2026 through web retrieval and examination of publisher, PubMed and institutional records. Eligibility was restricted to English-language research with a bibliographic year from 2011 to 2025. Queries included "sporting records comparability technology athletes philosophy," "running footwear response variability," "wind effects athletics performance," and "swimming course length turn performance." Searches by article title and author checked bibliographic identity and digital object identifiers.

Selection followed the inferential questions in the analysis. Philosophical articles addressed the relationship between rank, athletic merit and equipment acceptability. Biomechanical articles addressed metabolic cost, completion time, turn sections and wind resistance. Measurement discussions addressed repeated observations and individual response error. Record-statistics articles addressed the dependence of a minimum on the number of attempts. Average footwear benefits, adverse individual responses and measurement instability were considered together. The selection was targeted rather than exhaustive; no pooled effect or systematic-review screening total was calculated.

HANGZHOU RACE QUANTITIES

OMEGA timing identifies the finishing order and elapsed times in the 25 m pool (OMEGA, 2018). The section definitions and contrasts follow Polach et al.: the start ends at 10 m, each turn spans 5 m before to 5 m after wall contact, and the remaining distance is free swimming (Polach et al., 2021). Every contrast is Paltrinieri minus Romanchuk. Finish times were converted from minutes and seconds to seconds. Free-swimming and turn contrasts were retained to two decimal places.

For the completed race, total elapsed time equals start time plus free-swimming time plus accumulated turn time. The start contrast was calculated by subtracting the other two contrasts from the finish contrast. Its value therefore inherits the precision and discrepancies of those three inputs. No raw video was analyzed, and no segmentation-error interval was estimated. Reweighting turn time holds the completed sections fixed; it changes an arithmetic score rather than the physical course or the swimmers' movements.

RESULTS

EXPECTED COMPLETION TIME UNDER A DEFINED TASK

Write a completion task as

$$T = (D, C, E, M), \quad (1)$$

where D specifies distance and demanded movement, C specifies permitted actions and assistance, E specifies equipment and physical conditions, and M specifies timing and scoring. For a 1500 m freestyle swim, course length determines the frequency of turns, while section boundaries determine which elapsed intervals count as free swimming. The event name alone does not determine those quantities.

Let b denote physiological preparedness and movement skill. Let π denote an action policy: the rule governing pacing and execution in response to the task. For $x = (b, \pi)$, define capability by

$$\mu_T(x) = \mathbb{E}[Y^*(T; x)], \quad Y = \mu_T(x) + \eta + e, \quad (2)$$

where Y^* is elapsed completion time without observation error, $\eta = Y^* - \mu_T(x)$ is trial variation, and e is observation error. The expectation is over repetitions at the stipulated preparedness, policy and task conditions. The mean of η is zero by definition. A systematic timing offset must be corrected or included in M ; a zero mean for e requires evidence rather than assumption. Capability here is an expected task-specific time, not the minimum of an athlete's attempts.

A fixed-policy comparison changes T while holding b and the policy rule constant. The admissible comparison set must contain states whose rules are defined and legal under both tasks. If a course change requires a different turn sequence, the policy must specify its response to each course. A comparison after task-specific familiarization instead permits a condition-specific policy. Training that changes preparation or skill also changes b . Immediate equipment effects, familiarized technique and longer-term training effects are consequently different quantities.

Legal validity establishes whether recognition rules are satisfied. Numerical superiority establishes which observation is faster. Common-task superiority establishes which expected time $\mu_{T_0}(x)$ is smaller under a named task T_0 . One race can settle numerical superiority without estimating the expected margin across repetitions. A claim about expected capability requires repeated comparable observations or a validated performance model.

ORDER PRESERVATION AND CALIBRATION

For tasks T and T' on the same admissible set X , consider

$$\mu_{T'}(x) = h(\mu_T(x)), \quad x \in X, \quad (3)$$

where h is strictly increasing on attained expected times and does not depend separately on athlete identity.

Proposition 1 (Ordinal correspondence). *Eq. (3) holds for some strictly increasing h on the image of μ_T if and only if the two tasks preserve every strict pairwise order and every tie on X .*

Proof. Strict increase preserves strict inequalities, and equal inputs receive equal outputs. Conversely, for each attained value $u = \mu_T(x)$, set $h(u) = \mu_{T'}(x)$. Preservation of ties makes h well-defined; preservation of strict orders makes it strictly increasing. The argument requires no extension beyond the attained image and applies to finite and infinite sets. $\square$

The proposition characterizes an ordering. It does not identify equivalent movement mechanics. For a finite group with distinct times and identical ranks, a monotone curve can be constructed through all pairs after observation. That curve supplies no independent test of predictions for another athlete. Rounded finishing times also conceal differences between expected times. Empirical validation must therefore address the precision of both performance estimates and the range of the conversion.

Task identity has separate nominal, mechanical and ordinal meanings. Nominal identity retains the named achievement, such as 1500 m freestyle. Mechanical identity retains the relevant movement constraints, equipment and physical conditions. Ordinal equivalence retains the athlete ordering. A 25 m and a 50 m course can share nominal identity while differing mechanically; matching ranks in one sample would not remove that difference.

Numerical comparison across tasks additionally requires calibration. Under a common time saving $c > 0$, the transformation $h(t) = t - c$ preserves all within-task ranks. Raw cross-task times nevertheless differ by that saving. On task T' , an earlier athlete must be represented by $h(\mu_T(x_{\text{earlier}}))$ before comparison with $\mu_{T'}(x_{\text{later}})$. The ordering proposition establishes when a mapping exists; it does not estimate its numerical values.

DIFFERENTIAL TIME EFFECTS AND DECISION UNCERTAINTY

For athlete states A and B , let the expected margin under T be $\Delta = \mu_T(B) - \mu_T(A) > 0$. Define each task effect as $g_i = \mu_T(i) - \mu_{T'}(i)$, with $i \in \{A, B\}$. A positive g_i is a time saving; a negative value is a time loss. Subtraction gives

$$\Delta' = \Delta - G, \quad G = g_B - g_A. \quad (4)$$

Athlete B becomes faster when $G > \Delta$, and equality produces a tie. An average benefit does not bound the differential effect for a particular pair. This identity applies to the defined expected times; it does not assume that equipment effects are constant across speeds, distances or policies.

Suppose the expected margin lies in $[d_L, d_U]$ and the differential effect lies in $[g_L, g_U]$. Then

$$\Delta' \in [d_L - g_U, d_U - g_L]. \quad (5)$$

The smallest difference combines the smallest margin with the largest effect; the largest difference uses the opposite endpoints. For a tolerance $\tau \geq 0$ in seconds, the interval supports A as faster by more than τ when $d_L - g_U > \tau$. It supports B as faster by more than τ when $d_U - g_L < -\tau$. Otherwise neither ordering is established by this rule. The third outcome does not establish equivalent capability.

An observed margin $m = Y_B - Y_A$ can bound the expected margin if the total execution and observation errors satisfy $|\eta_A + e_A| \leq a_A$ and $|\eta_B + e_B| \leq a_B$. In that case,

$$\Delta \in [m - a_A - a_B, m + a_A + a_B]. \quad (6)$$

Timing resolution alone cannot justify these bounds because execution varies between trials. Repeated observations can instead estimate intervals for the expected margin and task effects. When the bounds are probabilistic, Eq. (5) inherits their simultaneous coverage. Dependencies between estimates must be retained when the same trials contribute to both intervals.

No such uncertainty interval is assigned to the Hangzhou section contrasts: repeated athlete observations and individual segmentation-error estimates are unavailable for that calculation. Eq. (5) states the evidence required for an expected-capability comparison. A point correction that exceeds a finish margin remains inconclusive when its uncertainty permits both orderings.

FINISH-MARGIN DECOMPOSITION IN HANGZHOU

The official elapsed times were 849.14 s for Romanchuk and 849.87 s for Paltrinieri (OMEGA, 2018). Free-swimming section times were 550.06 s and 545.35 s, respectively, and Paltrinieri accumulated 5.18 s more turn time (Polach et al., 2021). Table 1 summarizes the four signed elapsed-time differences.

TABLE 1. PALTRINIERI MINUS ROMANCHUK IN THE 2018 MEN'S 1500 M SHORT-COURSE FINAL

Elapsed-time quantity	Difference (s)
Free-swimming sections	−4.71
Accumulated turn sections	+5.18
Start section, calculated by subtraction	+0.26
Total course completion	+0.73

Total completion: OMEGA (2018). Free swimming and turns: Polach et al. (2021). The start difference equals $0.73 - (-4.71) - 5.18$ s; it is calculated rather than independently timed here.

For start time S , free-swimming time F and accumulated turn time U , write $Y = S + F + U$. With δ denoting Paltrinieri minus Romanchuk,

$$\delta_Y = \delta_S + \delta_F + \delta_U, \quad 0.73 = 0.26 - 4.71 + 5.18 \text{ s}. \quad (7)$$

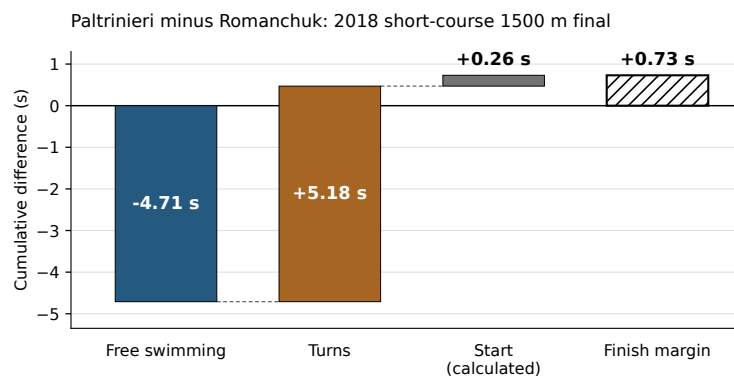


FIGURE 1. SECTION DIFFERENCES DETERMINING THE 0.73 S FINISH MARGIN IN HANGZHOU ON 16 DECEMBER 2018. EACH INCREMENT IS PALTRINIERI MINUS ROMANCHUK: FREE SWIMMING −4.71 S, TURNS +5.18 S AND CALCULATED START +0.26 S. POSITIVE INCREMENTS FAVOR ROMANCHUK.

The combined start and turn difference was 5.44 s. It exceeded Paltrinieri's 4.71 s advantage in free swimming and yielded Romanchuk's faster total completion. Figure 1 shows the accumulation of these section differences. Total completion

ranks performance of the full 25 m course; free-swimming time ranks the distance remaining after the defined start and turn sections.

Changing the weight of completed turn time gives the arithmetic score $J_\lambda = S + F + \lambda U$, where λ is dimensionless. The actual finish time has $\lambda = 1$. For these two swimmers,

$$\delta J_\lambda = -4.45 + 5.18\lambda \text{ s}, \quad \lambda_{\text{tie}} = \frac{4.45}{5.18} \approx 0.859. \quad (8)$$

Paltrinieri has the lower score below this weight, and Romanchuk has the lower score above it. The calculation holds every section time fixed. It therefore identifies the dependence of the ordering on the counted movement sections, rather than the outcome of a different swimming event. Setting $\lambda = 0$ leaves the swimmers' actual wall contacts, recovery opportunities and pacing embedded in S and F ; it cannot reconstruct a continuous swim without turns.

A 1500 m course has 59 turns in a 25 m pool and 29 in a 50 m pool. Course length changes the frequency with which turn proficiency can affect the finish time. Wolfrum et al. found a mean $2.0 \pm 0.6\%$ short-course advantage in swimming speed across national and international freestyle samples (Wolfrum et al., 2013). At fixed distance, a uniform 2% speed increase corresponds to $1 - 1/1.02 \approx 1.96\%$ less time. The mean speed difference neither supplies the identical percentage time adjustment nor determines each swimmer's course effect. The Hangzhou comparison concerns section and finish order within one race; a cross-course prediction requires measurements under both course conditions.

FOOTWEAR AND WIND ADJUSTMENTS

An energetic saving and a completion-time saving are different outcomes. In 18 runners tested at three speeds, Hoogkamer et al. found approximately 4% lower energetic cost in prototype marathon footwear at matched shoe mass (Hoogkamer et al., 2018). Kipp et al. relate the predicted speed change to the metabolic cost-velocity function (Kipp et al., 2019). Race-time conversion must therefore specify speed, distance and the assumed energetic relationship rather than copy the laboratory percentage.

Knopp et al. observed energetic benefits and detriments across footwear models in seven world-class Kenyan and seven European amateur male runners (Knopp et al., 2023). The individual differences make athlete-equipment interaction relevant, but a difference between single trials cannot isolate a stable personal effect. Barrons et al. emphasize repeated running-economy measurements for this purpose (Barrons et al., 2024). Applying Eq. (4) requires the differential expected time effect, including uncertainty in any conversion from energetic cost to completion time.

For wind, Moinat et al. analyzed 51,889 performances across 7,145 athlete seasons (Moinat et al., 2018). Their 100 m estimate at a 2.0 m s^{-1} tailwind is approximately 0.125 s for a 12 s performance, with the effect varying by performance level. A correction must identify the standardized wind condition and the supported performance range. Recognition of a mark within a permitted wind range does not imply equal aerodynamic resistance throughout that range.

ATTEMPT FREQUENCY AND THE PERFORMANCE MINIMUM

Let $Y_1, \dots, Y_n$ be independent completion times with the same unchanged distribution function H , and define $R_n = \min(Y_1, \dots, Y_n)$. Independence gives

$$\Pr(R_n > r) = [1 - H(r)]^n. \quad (9)$$

For $0 < H(r) < 1$, the probability that the minimum remains above r decreases with additional attempts. If H is continuous, symmetry assigns each observation the same probability of being the unique minimum; the probability that attempt n is a record is therefore $1/n$. These are established record-statistical results (Wergen, 2013).

A lower record is consequently compatible with an unchanged performance distribution. It may also accompany a task change, an athlete improvement or changes in selection. The minimum alone does not separate these processes. Radicchi examines Olympic performance progression under explicit statistical assumptions (Radicchi, 2012); forecasting an observed trajectory does not isolate its physiological causes. Actual attempts can be correlated and nonstationary. Eq. (9) establishes the opportunity effect under stated assumptions rather than claiming independent repetitions throughout sporting history.

DISCUSSION

WHICH MOTOR ACHIEVEMENT DOES THE COMPARISON RANK?

Romanchuk's finish and Paltrinieri's free-swimming sections demonstrate the importance of the scored achievement. The total includes the start and turns; the free-swimming sum excludes their elapsed intervals. Those totals support

different orderings because they contain different motor components. The result does not require an assumption that one swimmer had greater physiological capacity. It follows directly from the specified section boundaries and the signed time differences.

The turn-weight calculation makes that dependence explicit. The two scores coincide at $\lambda \approx 0.859$, although the swimmers' completed movements remain unchanged. This threshold describes the arithmetic composition of the score. A physical course change could additionally alter fatigue, breath holding, pacing and stroke execution, so Eq. (8) cannot supply a 50 m pool prediction. Removing a component from the recorded total is different from removing its effects on subsequent movement.

Sports Theory must therefore distinguish continuity of a named event from continuity of the performance it measures. An unchanged distance and stroke preserve nominal identity. Maintaining the same resistance and action constraints concerns mechanical identity. Maintaining an athlete ordering concerns ordinal equivalence. The order-preservation proof connects only the last of these to a monotone mapping. A task comparison needs a substantive account of the first two before the mapping can be interpreted as measuring the same movement capability.

Equipment governance also requires a separate sporting judgment. Burns and Tam discuss regulation of road-running footwear (Burns and Tam, 2020); Dyer examines several criteria of acceptability (Dyer, 2020). Equal access to a shoe does not establish equal time savings. A permitted innovation may reward useful technical adaptation while narrowing the defensible claim of cross-era superiority. Whether those interactions belong in the sport is a normative decision; their magnitude and stability are questions for measurement.

ESTIMATING A COMPARISON UNDER COMMON CONDITIONS

The target task must be specified before fitting a time correction. Table 2 ties the quantities in Eqs. (2)–(5) to the observations required for their estimation. In a footwear comparison, balanced repeated measurements under each shoe condition can distinguish execution variation from a persistent individual response. Preparedness, fatigue, condition order and familiarization determine the interpretation of that response. A fixed-policy trial and a trial after condition-specific training estimate different effects.

TABLE 2. DEFINITIONS AND OBSERVATIONS REQUIRED TO ESTIMATE COMMON-TASK SUPERIORITY

Quantity	Definition	Required observations
Task T_0	Distance, legal movement, equipment, environment and timing	Condition records for each compared completion
State $x = (b, \pi)$	Preparedness, skill and pacing/execution rule	Familiarization, fatigue and training-state assessments
Expected time $\mu_T(x)$	Mean elapsed time at the defined task and state	Repeated calibrated completions under each condition
Conversion h	Athlete-independent relation between task times	Paired calibration observations and separate validation observations
Margin and effect	$\Delta = \mu_T(B) - \mu_T(A); G = g_B - g_A$	Joint estimates and simultaneous uncertainty bounds
Tolerance τ	Smallest practically relevant difference in seconds	A threshold specified before examining the comparison
Attempt count n	Opportunities contributing to the minimum	Attempt histories, selection rules and dependence information

Estimating h requires quantitative prediction, not only matching ranks. Calibration observations should be separated from validation observations. Residuals should be examined by athlete, performance level and technique. If a common mapping fails, an athlete-specific prediction requires additional explanatory information. It cannot be relabeled a universal conversion.

For a pair of athletes, the expected margin and differential effect enter Eq. (5) together. When the resulting bounds lie on one side of the prespecified tolerance, they support a task-specific ordering. When they permit either ordering, the comparison remains unresolved. A single personal best cannot estimate both the expected margin and its trial variation.

TRAINING INTERPRETATION AND ANALYTICAL LIMITS

For a swimmer, a faster total obtained through improved turns is a course-performance improvement. A claim about free-swimming speed instead requires the free-swimming sections. For a runner, a personal best after a shoe change establishes the faster completion but does not isolate conditioning from the shoe effect. Training assessment should match its movement or physiological question to the quantity measured.

Expected elapsed time depends on the stipulated repetitions and preparedness. Exact order preservation is stronger than the approximate stability observable in competition. The interval calculation includes all endpoint combinations and can be conservative when its inputs are dependent. It does not estimate those inputs or replace a joint statistical model. The Hangzhou calculation uses two finishers in one race; two-decimal display precision does not quantify video segmentation error or repeatable personal capability.

Start, turn and free-swimming times sum arithmetically, but their physiological causes are interdependent. Turn execution can alter subsequent speed and fatigue. The fixed-section score retains those interactions and cannot isolate the outcome of removing wall contacts. Across years, preparation, selection, equipment and action policies may change simultaneously. Their separate effects require observations beyond the record minimum. Judged performances and opponent-dependent games also require other achievement variables before these completion-time arguments can be applied.

CONCLUSIONS

Romanchuk's 0.73 s finish advantage coexisted with Paltrinieri's faster free-swimming sections because the total course included the start and turns. A faster sporting mark therefore ranks a specified achievement; its interpretation depends on the movement components and physical conditions counted in that achievement. Across tasks, common-athlete comparison requires an expected-time definition, an admissible policy, a calibrated relation between conditions and uncertainty for the adjusted margin. Preserved rankings do not establish identical mechanics or an independently validated conversion. Differential time effects can reverse an order when they exceed the preceding margin. More attempts can also lower a record minimum under an unchanged distribution. These conditions delimit athlete superiority claims while retaining the full competitive meaning of recognized completion results.

DECLARATIONS

CONFLICT OF INTEREST

The author declares that there are no conflicts of interest related to this study.

DATA AVAILABILITY

No dataset were available for this research.

FUNDING

This research was funded by Seoul National University.

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