Analysis of continuous gait data requires temporal alignment of gait phases

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Human gait (walking) is a cyclical activity that consists of phases defined by events. Each event can be used as the start of the gait cycle.

Gait cycle start point	The order of gait cycle events and phases at each definition
Ipsilateral heel contact	Loading Response (LR) → Mid & Terminal Stance (MTSt) → Pre-Swing (PS) → Initial & Mid Swing (IMSw) → Terminal Swing (TS)
Contralateral toe-off	MTSt → PS → IMSw → TS → LR
Contralateral heel contact	PS → IMSw → TS → LR → MTSt
Ipsilateral toe-off	IMSw → TS → LR → MTSt → PS
Ipsilateral vertical shank position	TS → LR → MTSt → PS → IMSw

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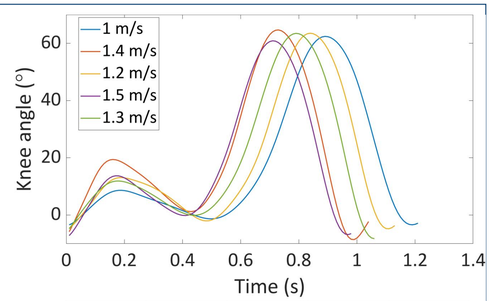
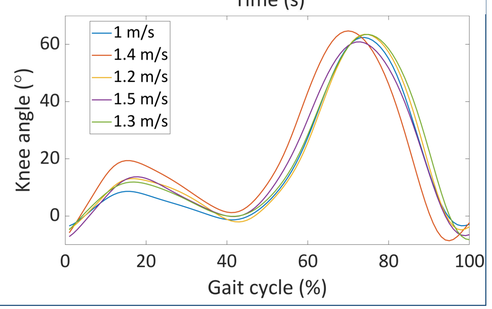
The duration (time, s) of each gait cycle varies with repetition and interventions such as walking speed (m/s).



Typically, a gait cycle is normalized to 100% for **point-by-point comparison** between conditions.



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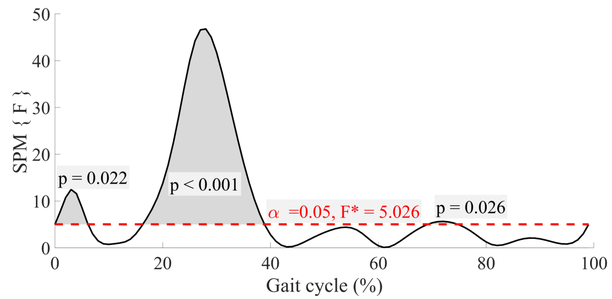
Statistical Parametric Mapping (SPM) compares time normalized gait cycles from different speeds, point-by-point (%).



Above, SPM provides an F-statistic curve (black curve), revealing the % of gait cycle when knee angle differs significantly ($p < 0.05$) between five gait speeds (curve above critical F indicated by red dashed line).

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SPM results maybe sensitive to the definition of the start of each gait cycle (Honert & Pataky, 2021).

However, **temporal alignment** of phases, not just normalization of the gait cycle to 100%, maybe necessary for accurate point-by-point comparison of the gait cycle (Helwing et al. 2011).

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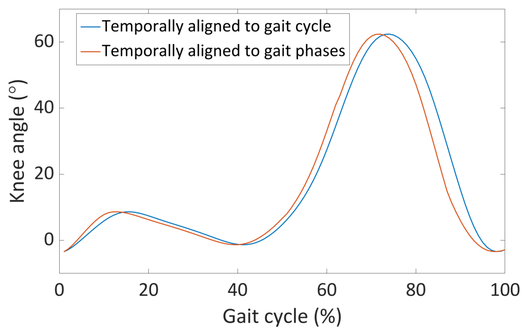
Temporal alignment of gait phases refers to the process of normalizing time for each phase of the gait cycle, rather than for only the entire gait cycle.



Without temporal alignment of gait phases, different gait phases may occur at the same % of the gait cycle (e.g., terminal swing and loading response).

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Current study, compares SPM results for five different gait speeds using:

i. Five different definitions of the gait cycle start point.
ii. Normalization to only the gait cycle versus temporal alignment to the gait phases.

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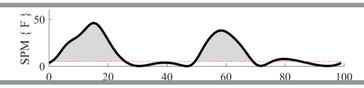
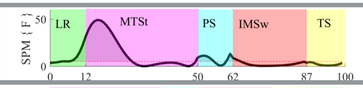
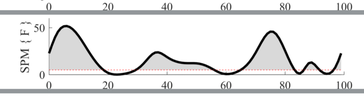
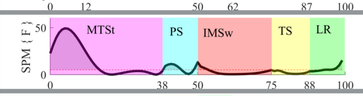
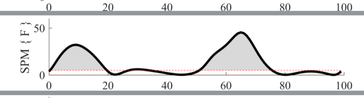
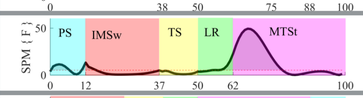
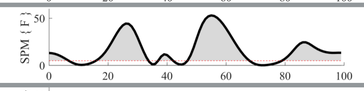
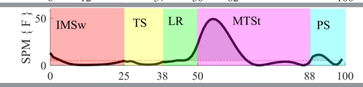
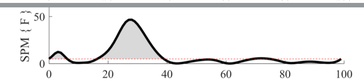
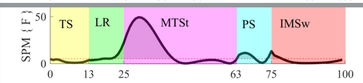
Gait cycle start point	Inconsistent SPM results in data normalized only to gait cycle	Consistent SPM results in data temporally aligned to gait phases
Ipsilateral heel contact		
Contralateral toe-off		
Contralateral heel contact		
Ipsilateral toe-off		
Ipsilateral vertical shank position		

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Temporal alignment of gait phases ensures consistent SPM results, whereas changes in cycle start definition without such alignment lead to inconsistent SPM outcomes.

References:
Honert, E C. et al. (2021) J Biomech, 119:110329. 10.1016/j.jbiomech.2021.110329
Helwig, N. E. et al. (2011). J Biomech, 44(3):561–566. 10.1016/j.jbiomech.2010.09.015