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Time-activity budget in horses and ponies: A systematic review and meta-analysis on feeding dynamics and management implications

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ABSTRACT

Background: The time-activity budget is a key indicator of animal welfare. This meta-analysis integrated 14 studies (1979-2020) with 364 horses under wild, natural-living, and stabled conditions to evaluate feeding, resting, standing, and locomotion.
Aim: The study aimed to categorize daily behavioural patterns in equines, with emphasis on feeding behaviour.
Methods: Fixed and random effects models, forest plots, and ANOVA assessed the influence of management, sociality, sex, age, body size, and feeding type. *Results:* Feeding was greater in free-ranging (56 %) than stabled horses (38 %; $p < 0.0001$), in grouped (54 %) vs. isolated (39 %; $p = 0.0052$), in females (64 %) vs. males (48 %; $p = 0.0253$), and in grazing (56 %) vs. hay-fed horses (39 %; $p = 0.0003$). Resting was higher in young, small, grouped, and grazing horses. Standing was commoner in stabled, isolated, adult, larger, and hay-fed animals. Locomotion increased in free-ranging, grouped, and grazing horses.
Conclusion: Management promoting foraging, social interaction, and locomotion enhances equine welfare.

1. Introduction

Animal welfare is a multidimensional and evolving concept that requires objective, measurable, and unequivocal evaluation parameters grounded in robust scientific evidence [1,2]. Over the years, the scientific community focusing on animal welfare has transitioned from welfare assessments based on resource-based indicators (such as housing type or feed quantity), to animal-based indicators, emphasizing the physical and mental state of the animal and its capacity to exhibit species-specific behavioural repertoires. These indicators align with the "Three Fs" framework - Foraging, Friends, and Freedom - which emphasizes the critical importance of enabling natural foraging behaviour, social interaction, and voluntary movement to safeguard equine welfare. This shift aligns with the understanding that welfare is rooted in an individual's subjective experience [3].

Among the numerous animal-based indicators, health status (e.g., physical injuries or changes in body condition score), posture and gait (e.g., ear and neck positions), physiological parameters (e.g., cortisol concentration, heart rate variability), and behaviour (e.g., stereotypies, cognitive biases, or deviations in the time-activity budget) are widely used to evaluate welfare [4]. The time-activity budget, a method measuring the proportion of time an animal allocates to specific behaviours over a given period, has gained prominence as a welfare indicator [5]. It provides insights into the extent to which the frequency and duration of specific behaviours deviate from those observed in natural settings [6]. The time-activity budget is influenced by various factors, including environmental structure, spatiotemporal variations in resource availability, abrupt seasonal changes in abiotic conditions, and anthropogenic disturbances [7]. Under normal conditions, horses distribute their time among fundamental activities in a consistent, repetitive daily routine that is unique to each individual. For this reason, analysing their time-activity budget provides a valuable metric for assessing welfare [8].

Feral horses serve as an essential reference, as domestic horses allowed to express species-specific behaviours in environments replicating their natural habitat exhibit time budgets comparable to their wild counterparts [4,9]. However, stabling often restricts movement, foraging opportunity, and social interactions [10,11]. These conditions introduce significant deviations from natural behaviours, raising welfare concerns. Scientific understanding of horse time budgets remains incomplete, hindering detailed comparisons within and across species. Previous systematic reviews, such as Auer et al. [3], analysed time

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budgets of domesticated and semi-feral horses but were constrained by small sample sizes, variability in observation methods, and a lack of statistical meta-analyses, limiting the generalizability of their conclusions.

The purpose of this study was to examine and categorize the daily behavioural patterns of equines, with a primary focus on feeding behaviour, while also considering other activities such as lying, standing, and overall movement. The analysis involved a diverse set of studies, incorporating both wild and domesticated horses, and explored how feeding habits and other behaviours are influenced by various factors, including management conditions (free-ranging vs. indoor), social context (individual vs. group housing), age (over 3 years vs. 1–3 years), size (horses vs. ponies), sex (female, male, or mixed groups), and diet type (grazing vs. hay-based).

2. Materials and methods

The search was limited to Scopus, Elsevier's bibliographic and citation database, due to its broad multidisciplinary coverage and indexing of major veterinary and animal science journals. We acknowledge this as a limitation and encourage future reviews to consider additional databases for broader inclusion. The search covered studies published between 1979 and August 2023, and began in August 2023, following the research protocol's flowchart (Fig. 1).

The keywords used for conducting the database search were: "Equines," "Feeding system," "Budget time," "Pony," "Horses," "Behaviour," "Feeding patterns," and "Feed intake controls." Additionally, relevant articles were also identified through backward citation tracking from the bibliographies of initially retrieved records. These additional articles were included in the total count of 40 records shown in Fig. 1, as part of the identification phase of the PRISMA workflow. A total of 40 records were identified, comprising 37 from the Scopus database search and 3 from backward citation tracking. As no duplicates were present, the number of records identified coincided with the number screened. Following data collection, a Microsoft Excel spreadsheet titled "Data daily" was created, containing data on the average time spent by subjects on behaviours such as feeding, lying, standing, and activity over a 24 h period. The work involved categorizing each behaviour (Feeding, Lying, Standing, and Activity) into various categories and identifying contrasting aspects of the subjects' lifestyles, such as: Management (Freedom vs. Indoor), Sociality (Alone vs. Group), Age (>3 years vs. 1-3 years), Size (Horse vs. Pony), Sex (Female vs. Male vs. Mixed), and Feeding type (Grazing vs. Hay). To ensure consistency in behavioural interpretation, each category was defined based on common ethological standards and descriptions provided in the original studies. The feeding category included all behaviours associated with food intake, such as grazing (pasture), browsing (shrubs or trees), consumption of hay or concentrate feeds, and use of feeding devices (e.g., haynets or feed buckets). The lying category included sternal and lateral recumbency, regardless of sleep state. Standing behaviour referred to upright stationary posture, encompassing both passive standing and attentive alert postures. The activity category was restricted to locomotion-related behaviours such as walking, trotting, or free movement within the paddock or stall, and did not include play, stereotypies, or investigative behaviour unless these overlapped with forward movement. Management-related variables were also standardized. The term "indoor" referred to horses housed in individual or group stalls for 24 h per day, with no reported access to turnout or pasture during the observation period. Conversely, "freedom" (or free-ranging) described horses kept with continuous or near-continuous access to outdoor environments, including pasture, paddocks, or natural landscapes, where movement was not restricted. Social housing was classified as "group" when horses had physical and visual access to conspecifics and engaged in social interactions, while "alone" referred to horses housed in full isolation, with no direct contact with other equids.

All data extracted from the scientific literature on the topic were further divided based on: region, number of individuals studied, sex, age, sociality (whether kept alone or in groups), type of environment (pasture, free, stall, or paddock), duration of the study, and type of feed provided to the horses. The initial search identified a total of 40 articles, which were screened by reading their titles and abstracts. Of these, 18 documents were deemed irrelevant and did not meet the eligibility criteria, primarily due to the absence of a DOI or lack of relevance to the study topics, leaving 22 articles for full-text review. Eight of these were further excluded because they did not contain data on the specific parameters being analysed. For inclusion in the meta-analysis, studies had to meet several criteria: they needed to focus specifically on horses or ponies and report quantitative data on the time allocation to at least one behavioural category (feeding, lying, standing, or locomotion) over a 24-hour observation period. Furthermore, included studies had to

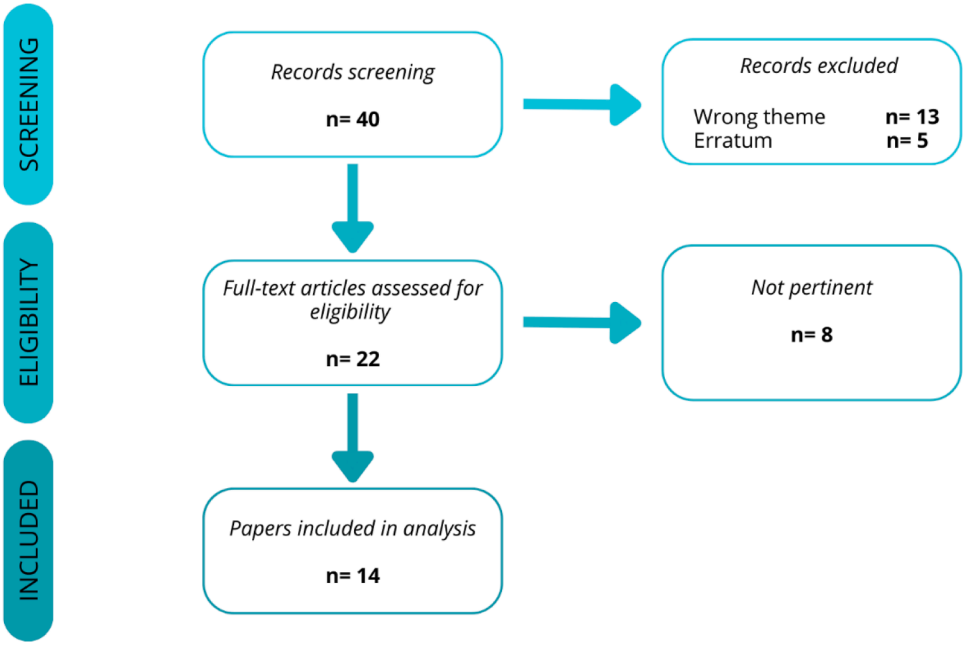

Fig. 1. Flowchart of the Literature Search Protocol (Adapted from [12]).

provide sufficient detail on contextual variables such as the management system (e.g., indoor or outdoor housing), social housing arrangement (individual or group), feeding type (hay or grazing), age, body size, or sex. Only peer-reviewed journal articles published between 1979 and August 2023 were considered. Studies were excluded if they provided only partial or narrative behavioural descriptions without quantitative time allocations, or if they focused only on physiological, training, or performance outcomes without reference to behavioural time budgets. Additionally, articles that did not report on horses or ponies as distinct groups (for example, those including data on other equid species without disaggregation) were excluded. Lastly, studies were excluded if the observation duration was shorter than 12 h and lacked appropriate extrapolation to a full daily cycle. The categories considered for statistical analysis were feeding, lying, standing, and activity.

The meta-analysis was performed using the forest plot technique, which graphically represents the consistency and reliability of the results reported in the studies included in the analysis. Different models (random effect and common effect) were evaluated using the total number of observations and the proportion of specific activities (Total Feeding,%; Total Lying,%; Total Standing,%; Total Activity,%). In this study, the forest plot was created using RStudio (v1.3.959; 11) with the packages "tidyverse," "meta," and "metaphor" [13–15]. Subsequently, an analysis of variance was conducted to assess the impact of individual fixed effects (Management, Sociality, Age, Size, Sex, and Feeding type) on the specific activities under study, as reported in previous studies [16].

3. Results

As a result, only 14 studies met the eligibility and data completeness criteria for inclusion in the meta-analysis (Fig. 1). The studies included in the meta-analysis were conducted between 1979 and 2020, with a total of 364 subjects. In terms of geographical origin, 12 of the included studies were conducted in the Northern Hemisphere (primarily in Europe and North America), while 2 studies were conducted in Australia, representing the Southern Hemisphere.

3.1. Total feeding

The average time spent by subjects on feeding activities across the studies considered was approximately 50 % (49.3 % [48.3-50.3] common effect and 53.1 % [47.0-59.0] random effect), with some studies reporting values above or below this average.

In some studies [17–19] the percentage of time dedicated to feeding exceeds the average (Fig. 2). Conversely, studies reporting values below the average included Ralston et al. [20], Ogilvie-Graham [21], Martin Rosset [22], Raspa et al. [23], and Laut et al. [24], as shown in Fig. 2, column IV, Fixed + random, 95 % CI.

The studies that carried the most weight in the analysis were Keiper and Keenan [25] and Ogilvie-Graham [21], as indicated by the Weight (common) percentage, which reflects the influence fixed factors.

Regarding the percentage of time spent feeding (Total feeding,%), statistical analysis revealed a significant difference ($p < 0.05$) for the following parameters: management type (Management; Freedom vs. Indoor), sociality (Sociality; Alone vs. Group), sex (Sex; Female vs. Male vs. Mix), and feeding type (Feeding type; Grazing vs. Hay). Age (Age; >3 years vs. 1-3 years) and size (Size; Horse vs. Pony) did not significantly influence the time subjects dedicated to this behaviour.

Regarding the type of animal management (Freedom vs. Indoor), subjects managed under free conditions spent a significantly higher percentage of time on feeding activities (56.4 ± 2.309 %) compared to those housed indoors (38.162 ± 2.915 %; Table 1). Conversely, animals living alone (Alone) spent a lower percentage of time on feeding activities (39.4 ± 3.840 %) compared to those living in groups (Group) (54.262 ± 2.694 %; Table 1).

In this study, sex (Sex; Female vs. Male vs. Mix) also proved to be a relevant factor in determining the percentage of time spent on feeding. Female subjects (Female) showed higher percentages (64.4 ± 5.513 %) compared to mixed-gender groups (Mix) (46.114 ± 2.603 %; Table 1).

The type of feed used (Feeding type), specifically Grazing vs. Hay, was also examined. Results indicated that subjects fed by grazing spent a significantly higher percentage of time on feeding activities (56.3 ± 2.496 %) compared to those fed hay (39.322 ± 2.960 %; Table 1).

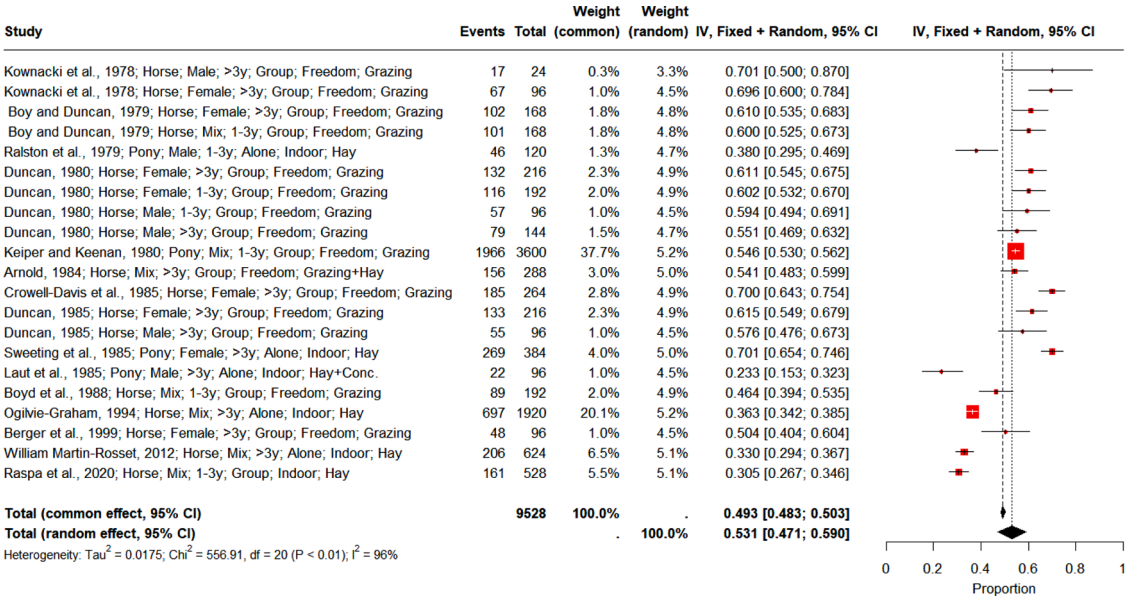

Fig. 2. Summary forest plot of the studies included in the analysis based on the Total Feeding behaviour variable. Events = number of hours sampled in the study related to the event considered (Total Feeding); Total = total number of hours evaluated in the study; Weight (common) = weight of fixed factors; Weight (random) = weight of random factors (sample size); CI = 95 % confidence interval; Tau^2 = index of effect size dispersion; Chi^2 = Cochran's Q test; df = degrees of freedom; $P = p$-value; I^2 = Higgins' statistic.

Table 1
Analysis of variance for Total Feeding Behaviour variable (%). The table analyses the Total Feeding behaviour in relation to the following factors: Management (Freedom vs. Indoor), Sociality (Alone vs. Group), Sex (Female vs. Male vs. Mixed), and Feeding Type (Grazing vs. Hay). It presents the mean (average value), standard error (indicating the variability of the mean estimate), Lower 95 % and Upper 95 % (confidence interval bounds), and Prob > *F* (p-value indicating the statistical significance of each factor).

Factors	Mean	Std Error	Lower 95 %	Upper 95 %	Prob > *F*
Management					<.0001*
Freedom	56.4002	2.3086	51.568	61.232	
Indoor	38.1617	2.9153	32.060	44.264	
Sociality					0.0052*
Alone	39.4400	3.8401	31.403	47.477	
Group	54.2622	2.6949	48.622	59.903	
Sex					0.0253*
Female	64.4686	5.5134	52.885	76.052	
Male	47.9887	9.2804	28.491	67.486	
Mix	46.1141	2.6033	40.645	51.583	
Feeding type					0.0003*
Grazing	56.5179	2.4967	51.292	61.744	
Hay	39.3227	2.9605	33.126	45.519	

3.2. Total lying

The average time spent by subjects on resting activities across the studies considered was approximately 15 % (14.6 % [13.9-14.4] common effect and 8.1 % [4.0-13.4] random effect), with some studies reporting values above or below this average.

The studies where the percentage of time dedicated to resting exceeded the average were Keiper and Keenan [25] and Raspa et al. [23] (Fig. 3). Conversely, studies reporting values below the average included Kownacki et al. [17], Boy and Duncan [26], Duncan [27], Duncan [28], Sweeting et al. [18], Boyd et al. [29] and Ogilvie-Graham [21], as shown in Fig. 3, column IV, Fixed + Random, 95 % CI.

The studies that carried the most weight in the analysis were Keiper and Keenan [25] and Ogilvie-Graham [21], as indicated by the Weight (common) percentage, which reflects the influence of fixed factors.

Statistical analysis of the percentage of time spent resting (Total lying,%) revealed a significant difference ($p < 0.05$) for the following parameters: sociality (Sociality; Alone vs. Group), age (Age; >3 years vs. 1–3 years), feeding type (Feeding type; Grazing vs. Hay), and size (Size; Horse vs. Pony; Table 2). The factors of management type (Management; Freedom vs. Indoor) and sex (Sex; Female vs. Male vs. Mix) did not significantly influence the time spent by the subjects in this behaviour.

Regarding sociality (Alone vs. Group), subjects kept in groups with their conspecifics spent a significantly higher percentage of time lying down (20.236 ± 2.570 %) compared to those managed alone (6.141 ± 4.155 %; Table 2). Another relevant variable in our study on resting time was age (Age); the reference groups analysed were individuals older than 3 years (>3 years) and individuals aged 1–3 years. It was found that horses under 3 years spent a higher percentage of time resting (lying down; 24.176 ± 1.728 %) compared to horses older than 3 years (5.795 ± 2.004 %; Table 2).

Additionally, we calculated the percentage of time spent resting based on size (Size). Horses (Horse) spent significantly less time resting (8.745 ± 2.449 %) compared to ponies, whose resting percentage was markedly higher (24.614 ± 2.557 %; Table 2).

Lastly, a relevant variable analysed regarding resting time (Lying) was feeding management, specifically how the horses were fed (Hay vs. Grazing). Table 2 shows that individuals fed by grazing spent more time resting (20.442 ± 2.994 %) compared to those fed hay (9.483 ± 3.868

Table 2
Analysis of variance for Total Lying Behaviour (%). The table analyses the Total Lying behaviour in relation to the following factors: Sociality (Alone vs. Group), Age (>3 years vs. 1–3 years), and Size (Horse vs. Pony). It presents the mean (average value), standard error (indicating the variability of the mean estimate), Lower 95 % and Upper 95 % (confidence interval bounds), and Prob > *F* (p-value indicating the statistical significance of each factor).

Factors	Mean	Std Error	Lower 95 %	Upper 95 %	Prob > *F*
Sociality					0.0120*
Alone	6.1417	4.1557	−2.77	15.055	
Group	20.2364	2.5701	14.72	25.749	
Age					<.0001*
> 3 years	5.7954	2.0048	1.496	10.095	
1-3 years	24.1769	1.7289	20.469	27.885	
Size					0.0005*
Horse	8.7454	2.4492	3.492	13.999	
Pony	24.6145	2.5575	19.129	30.100	
Feeding type					0.0418*
Grazing	20.4427	2.9945	14.020	26.865	
Hay	9.4835	3.8689	1.186	17.781	

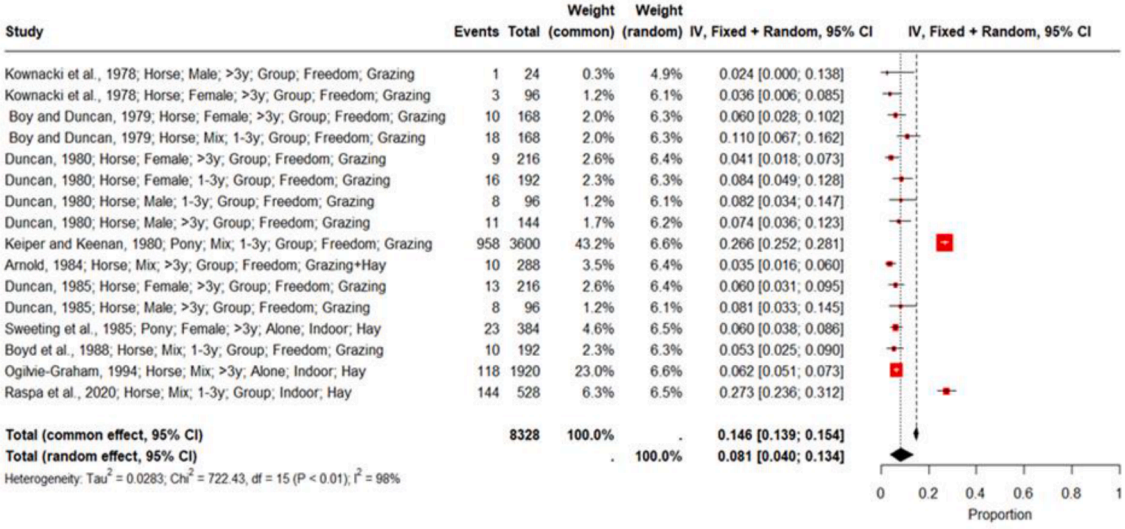

Fig. 3. Summary forest plot of the studies included in the analysis based on the Total Lying behaviour variable. Note: Events = number of hours sampled in the study related to the event considered (Total Lying); Total = total number of hours evaluated in the study; Weight (common) = weight of fixed factors; Weight (random) = weight of random factors (sample size); CI = 95 % confidence interval; Tau^2 = index of effect size dispersion; Chi^2 = Cochran's Q test; df = degrees of freedom; *P* = *p*-value; I^2 = Higgins' statistic.

%).

3.3. Total standing

The equines analysed in the various studies spent an average of approximately 32 % of their time in standing activities (31.8 % [30.8–32.9] common effect and 27.4 % [19.9–35.6] random effect), with some studies reporting values above or below this identified average.

The studies where the percentage of time spent standing exceeded the average were Arnold [30] and Ogilvie-Graham [21] as shown in Fig. 4. Conversely, studies reporting values below the average included Boy and Duncan [26], Duncan [27], Sweeting et al. [18] and Boyd et al. [29], as shown in Fig. 4, column IV, Fixed + Random, 95 % CI.

The studies that carried the most weight in the analysis were Keiper and Keenan [25] and Ogilvie-Graham [21], as indicated by the Weight (common) percentage, which reflects the influence of fixed factors.

Statistical analysis revealed a significant difference ($p < 0.05$) in the percentage of time spent standing (Total standing,%) concerning the following parameters: management type (Management; Freedom vs. Indoor), sociality (Sociality; Alone vs. Group), age (Age; >3 years vs. 1–3 years), size (Size; Horse vs. Pony), and feeding type (Feeding type; Grazing vs. Hay). Sex (Sex; Female vs. Male vs. Mix) did not show particular relevance (Table 3).

Regarding animal management type (Freedom vs. Indoor), subjects housed indoors spent a significantly higher percentage of time standing (47.3 ± 4.544 %) compared to those managed freely (24.886 ± 3.262 %; Table 3).

Next, analyzing the influence of sociality (Alone vs. Group) on standing activity using a box plot, isolated individuals (Alone) showed higher percentages (51.233 ± 4.491 %) compared to those kept in groups (Group) (25.383 ± 2.777 %; Table 3).

Age also emerged as an important variable, with notable differences in the total time spent standing: horses older than 3 years (>3 years) spent more time in this behaviour (43.799 ± 4.435 %) compared to younger individuals (1–3 years) (24.157 ± 3.825 %; Table 3).

Regarding size (Size), the analysis showed that horses spent more time standing (41.325 ± 4.180 %) compared to ponies, which had significantly lower percentages (22.950 ± 4.365 %; Table 3).

Lastly, for this standing activity variable, feeding management was considered. Subjects fed with hay (Hay) spent more time standing (47.067 ± 4.034 %) compared to those grazing (Grazing), who showed lower percentages (23.829 ± 3.122 %; Table 3).

Table 3
Analysis of variance for Total Standing Behaviour (%). The table analyses the Total Standing behaviour in relation to the following factors: Management (Freedom vs. Indoor), Sociality (Alone vs. Group), Age (>3 years vs. 1–3 years), Size (Horse vs. Pony), and Feeding Type (Grazing vs. Hay). It presents the mean (average value), standard error (indicating the variability of the mean estimate), Lower 95 % and Upper 95 % (confidence interval bounds), and Prob > *F* (p-value indicating the statistical significance of each factor).

Factors	Mean	Std Error	Lower 95 %	Upper 95 %	Prob > *F*
Management					0.0013*
Freedom	24.8863	3.2623	17.889	31.883	
Indoor	47.3790	4.5446	37.632	57.126	
Sociality					0.0002*
Alone	51.2333	4.4917	41.600	60.867	
Group	25.3836	2.7779	19.426	31.341	
Age					0.0047*
> 3 years	43.7994	4.4359	34.285	53.314	
1-3 years	24.1576	3.8255	15.953	32.363	
Size					0.0088*
Horse	41.3253	4.1804	32.359	50.291	
Pony	22.9506	4.3651	13.588	32.313	
Feeding type					0.0004*
Grazing	23.8293	3.1223	17.133	30.526	
Hay	47.0671	4.0340	38.415	55.719	

3.4. Total activity

The average time spent by subjects on activities across the studies considered was approximately 5 % (5.2 % [4.6–5.9] common effect and 5.9 % [4.8–7.2] random effect). No studies reported values above or below this identified average (Fig. 5).

The studies that carried the most weight in the analysis were Ogilvie-Graham [21] and Raspa et al. [23], as indicated by the Weight (common) percentage in Fig. 5, which reflects the influence of fixed factors.

Regarding the percentage of time spent on movement activities (Total activity,%), statistical analysis revealed a significant difference ($p < 0.05$) for the following parameters: management type (Management; Freedom vs. Indoor), sociality (Sociality; Alone vs. Group), and feeding type (Feeding type; Grazing vs. Hay; Table 4). The factors of sex (Sex; Female vs. Male vs. Mix), age (Age; >3 years vs. 1–3 years), and size

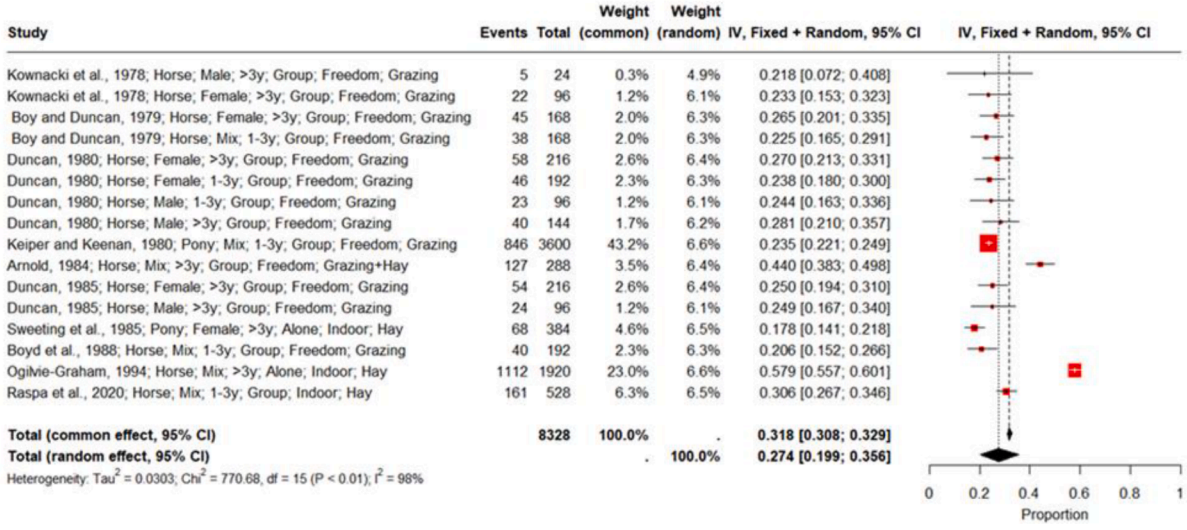

Fig. 4. Summary forest plot of the studies included in the analysis based on the Total Standing behaviour variable. Note: Events = number of hours sampled in the study related to the event considered (Total Standing); Total = total number of hours evaluated in the study; Weight (common) = weight of fixed factors; Weight (random) = weight of random factors (sample size); CI = 95 % confidence interval; Tau^2 = index of effect size dispersion; Chi^2 = Cochran's Q test; df = degrees of freedom; *P* = *p*-value; I^2 = Higgins' statistic.

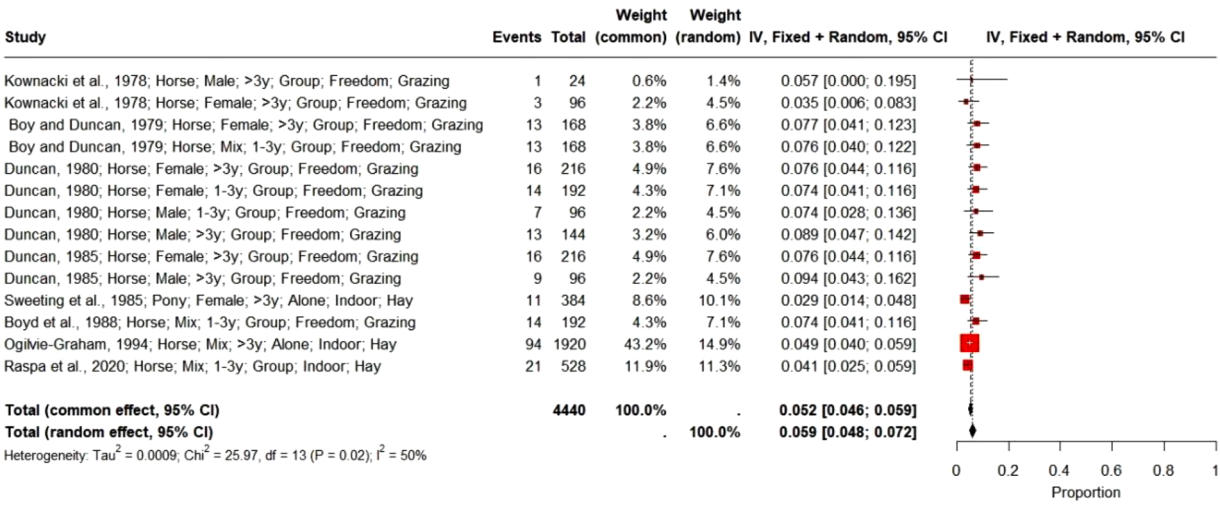

Fig. 5. Summary forest plot of the studies included in the analysis based on the Total Activity behaviour variable. Note: Events = number of hours sampled in the study related to the event considered (Total Activity); Total = total number of hours evaluated in the study; Weight (common) = weight of fixed factors; Weight (random) = weight of random factors (sample size); CI = 95 % confidence interval; Tau^2 = index of effect size dispersion; Chi^2 = Cochran's Q test; df = degrees of freedom; P = p-value; I^2 = Higgins' statistic.

Table 4
Analysis of variance for Total Activity Behaviour (%). The table analyses the Total Activity behaviour in relation to the following factors: Management (Freedom vs. Indoor), Sociality (Alone vs. Group), and Feeding Type (Grazing vs. Hay). It presents the mean (average value), standard error (indicating the variability of the mean estimate), Lower 95 % and Upper 95 % (confidence interval bounds), and Prob > F (p-value indicating the statistical significance of each factor).

Factors	Mean	Std Error	Lower 95 %	Upper 95 %	Prob > F
Management					0.0001*
Freedom	7.51307	0.43863	6.5574	8.4688	
Indoor	4.48763	0.33052	3.7675	5.2078	
Sociality					0.0220*
Alone	4.58333	0.54828	3.3887	5.7779	
Group	6.66198	0.56944	5.4213	7.9027	
Feeding type					0.0001*
Grazing	7.51307	0.43863	6.5574	8.4688	
Hay	4.48763	0.33052	3.7675	5.2078	

(Size; Horse vs. Pony) did not significantly influence the time subjects dedicated to this behaviour.

For animal management type (Freedom vs. Indoor), subjects living freely spent a significantly higher percentage of time on activity (7.51 ± 0.438 %) compared to those housed indoors (4.487 ± 0.330 %; Table 4).

Regarding sociality (Alone vs. Group), subjects in groups with their conspecifics spent a significantly higher percentage of time on activity (6.661 ± 0.569 %) compared to those managed alone (4.583 ± 0.548 %; Table 4).

Additionally, we calculated the percentage of time individuals spent engaging in activity based on their feeding type (Feeding type). Horses spent significantly less time moving when fed hay (Hay) (4.487 ± 0.330 %) compared to those grazing (Grazing), who spent more time in activity (7.51 ± 0.438 %), as shown in Table 4.

Fig. 6 offers a comprehensive visual summary of the study's findings, presenting the results of statistical analyses of variance for the four behavioural categories—feeding, lying, standing, and activity. These behaviours are depicted as histograms, showing the percentage of time allocated to each activity as influenced by the six primary factors examined in this study. Specifically: feeding type (Fig. 6a), with grazing versus hay feeding; sociality (Fig. 6b) with group versus isolated housing; sex (Fig. 6c), with female, male, and mixed-sex groups; age (Fig. 6d), with horses older than three years versus younger individuals (1–3 years); size (Fig. 6e), with horses versus ponies, and management (Fig. 6f), with free-ranging (pasture) versus indoor housing. A value exceeding 100 % is observed for grazing horses, a phenomenon attributed to the fact that the data were drawn from multiple distinct studies (Fig. 6).

These graphical representations complement the detailed statistical results provided earlier (e.g., Tables 1–4), enhancing the understanding of how feeding type, sociality, sex, age, size, and management collectively shape the behavioural patterns and welfare outcomes.

4. Discussion

Over the years, scientific studies have provided limited data on the daily time budgets of horses, resulting in insufficient information for detailed intra- and interspecific comparisons. This study addresses this gap by analysing data from 14 studies on 364 horses kept under different conditions and management systems. The analysis, conducted through a comprehensive meta-analysis and advanced statistical techniques such as mixed-effects models and variance analysis, explored the influence of various factors on time budgets. Only two papers focusing on ponies met the inclusion criteria, despite the search strategy being specifically designed to include the keyword "Pony." We acknowledge, however, that many equine breeds may meet pony height classifications without being explicitly labelled as "ponies" in the original publications. We reviewed available breed descriptions to identify animals likely to fall within this classification, but limited reporting on breed or height in some studies restricted further classification refinement. Their remarkably low representation highlights the fact that ponies remain significantly understudied, exposing a critical gap in the scientific literature.

4.1. Behaviours

This section explores the implications of the study's findings, focusing on the behavioural patterns observed in the subjects. The discussion emphasizes the importance of identifying and categorizing these behaviours to provide insight into the natural activities of horses and their adaptability to various environments. Behavioural activities such as feeding, lying, standing, and activity are examined in detail to establish a framework for evaluating equine time budgets and welfare outcomes.

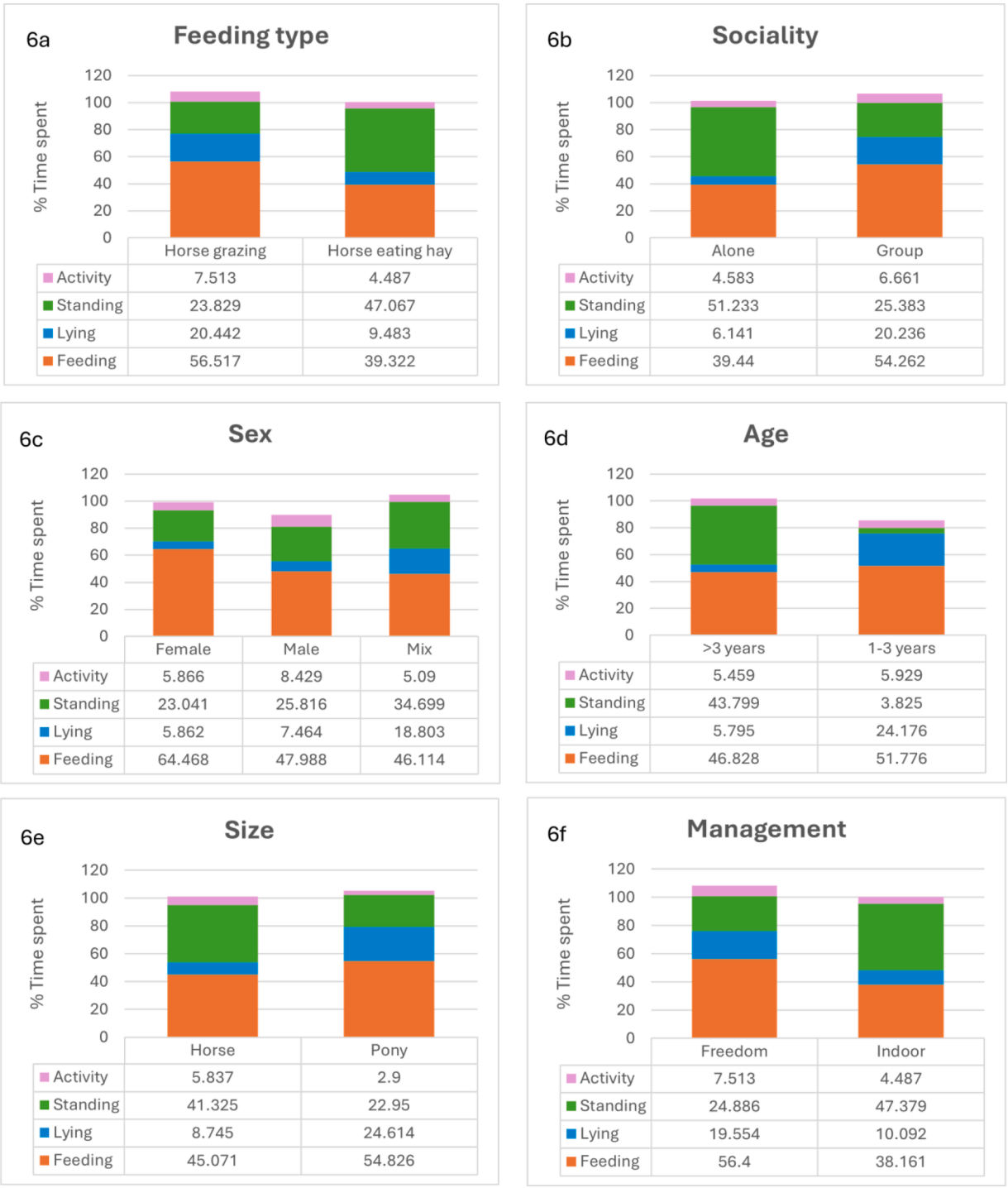

Fig. 6. Histograms showing the mean percentage of time spent in Total Feeding, Lying, Standing, and Activity behaviours, comparing grazing horses (Horse grazing) and horses eating hay (Horse eating hay; Fig. 6a); isolated horses (Alone) and horses in groups (Group; Fig. 6b); female horses (Female), male horses (Male), and mixed groups of males and females (Mix; Fig. 6c); horses older than 3 years (> 3 years) and horses aged 1 to 3 years (1–3 years; Fig. 6d); horses (Horse) and ponies (Pony; Fig. 6e); horses in their natural environment (Freedom) and horses managed in enclosed facilities (Indoor; Fig. 6f). The values represent the mean% time averaged across the included studies for each factor level.

4.1.1. Feeding behaviour and time

Horses evolved to continuously ingest small amounts of fiber-rich food, which is why they are described as trickle feeders [27,31]. Pasture management, as observed in this study, promotes longer feeding times and allows horses to exhibit their natural foraging behaviour, resulting in greater individual welfare [32]. In enclosed environments, shorter feeding durations and a potentially higher risk of stereotypic behaviours have been reported when haylage was offered on the floor with no straw available, compared to small-holed haynets or haylage on the floor with straw bedding [33]. Additionally, prolonged fasting periods further elevate the risk of developing gastric ulcers [34,35]. Specifically, the study revealed that horses managed freely (Freedom) spent a significantly higher percentage of time feeding (56.4% ± 2.31 %) compared to those housed indoors (38.16% ± 2.91 %; $p < 0.0001$).

Regarding sociality and its influence on the percentage of time spent feeding, feeding durations were notably lower in isolated horses (39.4%

± 3.84 %) than those in groups (54.26% ± 2.69 %; $p = 0.0052$). The presence of conspecifics positively influences feeding behaviour by promoting social facilitation. Auer et al. [3] provide valuable insights. Their study highlights behavioural differences between domesticated horses kept in separate stalls and free-ranging or semi-feral horses that live in conditions closer to their natural habitat. The daily feeding time budget ranged from 10 % to 66.6 %.

Significant sex-based differences were observed, with females showing the highest feeding times (64.4% ± 5.51 %) compared to males (47.99% ± 9.28 %) and mixed-sex groups (46.11% ± 2.60 %; $p = 0.0253$). In several studies, females were observed to have higher foraging times than males. One possible explanation is that lactating mares typically have elevated protein and energy requirements, which could influence feeding behaviour [36]. However, most studies included in our analysis did not report the reproductive status of the mares, and it is likely that many were not used for breeding. Therefore, this hypothesis should be interpreted with caution and validated in future research that includes reproductive status as a variable. To explain the results for mixed-sex groups (Mix), insights can be drawn from a study on two species of antelope in Africa [37,38]. It found that when males were accompanied by females, their grazing time increased due to the need to defend their territory.

Feeding type also played a critical role. Horses grazing on pasture spent a significantly greater percentage of time feeding (56.52% ± 2.50 %) compared to those fed hay (39.32% ± 2.96 %; $p = 0.0003$), emphasizing the importance of providing constant foraging opportunity throughout the day. Although several of the included studies reported the general season or time during which observations took place, this information was not consistently specific. Many studies referred to broad ranges such as “spring to autumn” or “grazing season,” without specifying exact months or pasture quality. As a result, season was not included as a factor in the meta-analysis, despite its acknowledged importance in influencing grass availability and grazing behaviour. One way to increase feeding duration, thereby reducing the risk of frustration and stereotypies, is the use of slow feeders. These devices regulate intake by extending the time required for forage consumption, and they are generally considered beneficial when appropriately designed. While hay nets are a common tool, several studies have highlighted that improper hole size or elevated positioning may cause ergonomic issues or increase frustration in horses, especially if not adjusted to individual needs [39]. However, while this method may help minimize stereotypic behaviours, it can also lead to frustration-related behaviours if not managed properly. In fact, the use of appropriate feeding devices can improve the management of stabled equines from a behavioural, nutritional, and sustainable point of view. From a sustainability perspective, particular attention should be given to the efficient use of raw materials, as reducing feed waste is increasingly important. For example, small-holed hay nets can help minimize hay losses, ensuring that more forage is consumed rather than wasted [40,41].

An important consideration when interpreting feeding duration is whether horses were fed ad libitum or under restricted regimes. Ad libitum access to forage more closely mimics natural foraging patterns and generally increases feeding time while reducing frustration behaviours [33,39]. However, in our analysis, the original studies varied in their reporting: while some studies (e.g., Sweeting et al., 1985; Raspa et al., 2020) involved ad libitum hay provision in group housing conditions, others did not specify feeding allowances. This introduces an important limitation, as reduced feeding time in stabled or isolated horses may reflect physical restriction rather than a behavioural preference. Future studies should report feeding schedules and allowance more consistently to allow clearer comparisons between free-choice and restricted conditions.

Two additional factors significantly influence feeding behaviour and welfare: diet composition and feed quality. High-fiber diets [23,42,43] extended feeding times and supported natural behaviours, reducing stress and the risk of colic [44], and improving overall welfare.

4.1.2. Lying behaviour and time

Studying the resting behaviour of horses is essential to quantitatively and qualitatively identify what constitutes normal sleep patterns for these animals and to determine whether changes in their sleep reflect broader welfare issues. Equine sleep is divided into Non-Rapid Eye Movement (NREM) and Rapid Eye Movement (REM phases), with the latter requiring recumbency and a relaxed postural state. Studies have shown that horses typically require around 2-3 h of sleep per 24 h cycle [45]. Sleep deprivation, particularly of REM sleep, has been linked to increased recumbency attempts and collapse episodes; altered routines, space limitations, and social stress can all fragment sleep and reduce its restorative quality [45]. Given the importance of both posture and uninterrupted lying periods, equine sleep should be better integrated into welfare assessments and future behavioural time-budget studies. While horses can rest both lying down and standing, this study specifically evaluated resting behaviour in the lying position. Resting behaviour, including lying down, is strongly influenced by group dynamics and social interaction, making it a key indicator of equine welfare. Horses kept in groups exhibit significantly more resting behaviour, with a mean lying time of 20.24% ± 2.57 %, compared to horses kept alone, which lie down only 6.14% ± 4.16 % of the time ($p = 0.0120$). This highlights the critical role of sociality in promoting optimal rest and welfare [45].

Age significantly affects lying behaviour; young horses (1–3 years) spend more time lying down (24.18% ± 1.73 %) compared to adults over three years (5.80% ± 2.00 %; $p < 0.0001$). Adult horses spend approximately 80 % of their resting time standing, dedicating a relatively small percentage of their 24 h day to lying down. Conversely, foals under three months old lie down for 70–80 % of their resting time, reflecting their developmental needs [18,26–28,30,46].

Size is another factor influencing lying behaviour. Ponies spend significantly more time lying down (24.61% ± 2.56 %) than horses (8.75% ± 2.45 %; $p = 0.0005$). It is believed that mature horses cannot remain in a fully lateral lying position for extended periods due to their weight and the respiratory fatigue that occurs when in this position for 15 min or more [45]. This also explains the differing results observed between horses and ponies.

Management practices and diet also indirectly influence lying behaviour. Horses fed a grazing-based diet spend more time lying down (20.44% ± 2.99 %) compared to those fed hay (9.48% ± 3.87 %; $p = 0.0418$). Both physical and psychological stressors can lead to a reduction in the duration and quality of sleep. Pain is an example of a physical stressor that impacts sleep [47]. Additionally, it is reported that diets rich in starch can negatively influence resting behaviour [43]. A high-fibre diet, instead, promotes natural behaviours, increases feeding time, and reduces stereotypies, thereby supporting overall welfare [48]. Furthermore, environmental factors like stocking density might have an impact on wellbeing measures in addition to food. Raspa et al. [49] demonstrated that increased space availability at the feed bunk had a favourable effect on several parameters, such as fewer feeding-related problems, better bedding amount, better mane and tail condition, less time spent resting in a standing position, and enhanced coat cleanliness. This emphasizes how welfare management is complex and how important environmental and dietary elements are.

4.2. Standing behaviour and time

The activity of "standing" is both a resting posture and a position of alertness for horses, adopted to remain vigilant against potential dangers or unfamiliar stimuli. This behaviour encompasses standing-resting and standing-attentive postures, leading to variability in definitions and making cross-study comparisons challenging.

Horses managed indoors (confined environments) spent significantly more time standing (47.38% ± 4.54 %) compared to those in free environments (24.89% ± 3.26 %; $p = 0.0013$). According to our meta-

analysis, indoor management practices limit opportunities for movement and foraging, resulting in static behaviours like standing becoming predominant. These findings align with Raspa et al. [49], who reported that confined horses in high-density group pens spent approximately 30.56 % of their time standing. Restricted environments thus alter the natural time budget of horses, reducing locomotion and resting behaviours.

Isolated horses exhibited a higher percentage of standing time (51.23% ± 4.49 %) than those in groups (25.38% ± 2.78 %; p = 0.0002). Social isolation increases stress and reduces dynamic interactions, resulting in prolonged periods of alert standing. Group living facilitates shared vigilance, reducing individual time spent standing. These findings are consistent with the behavioural adaptation observed in wild horses, where group settings naturally distribute vigilance tasks [50].

Age is a critical determinant of standing behaviour. Older horses (>3 years) spent more time standing (43.80% ± 4.44 %) compared to younger horses (1-3 years; 24.16% ± 3.83 %; p = 0.0047). This difference reflects the developmental needs of younger horses, who lie down more frequently for rest and growth. In the study by Kownacki et al. [17], which included a temporal analysis, it was observed that horses spent more time in an upright and attentive position at dawn and dusk, while dedicating much less time to lying down, particularly at night and in the morning. Reconfirming findings focused on resting (Lying), age was again found to significantly influence this behaviour. Younger horses (1–3 years) lie down much more frequently than adult horses (>3 years).

Horses spent more time standing (41.33% ± 4.18 %) than ponies (22.95% ± 4.37 %; p = 0.0088). This may be due to physiological differences, as larger body sizes may predispose horses to stand longer, while ponies, with different metabolic demands and energy dynamics, exhibit more active and varied behaviours. These distinctions emphasize the role of physical traits in shaping behavioural patterns. Bordin et al. [40] provided evidence to support this theory by showing how morphometric characteristics in ponies (Shetland vs. Welsh Cob) affected feeding behaviours including chewing activity and intake rate. The variations in standing behaviour between horses and ponies in this study may be explained by the influence of body size and other morphometric traits on other behavioural patterns. These differences highlight how important physical characteristics are in determining an equine's behaviour.

Feeding practices significantly impact standing behaviour. Horses fed hay spent significantly more time standing (47.07% ± 4.03 %) compared to those grazing (23.83% ± 3.12 %; p = 0.0004). Grazing promotes natural movement and foraging, reducing static postures. For example, a 500 kg horse requires approximately 1.5 h to consume 1 kg of pasture grass, compared to only 40 min to consume 1 kg of hay, referring to ingestion time and not to absolute dry matter intake [51]. Conversely, restricted hay feeding systems, such as those utilizing automatic feeders, lead to prolonged standing attentive behaviours. According to Seabra et al. [52], horses fed using automatic feeders that restrict feeding time spend significantly more time standing attentive (52.35 % of their time) compared to treatments with free choice feeding or slow feeders. High-starch diets are linked to increased stress markers and metabolic imbalances, leading to greater standing attentive behaviours. Conversely, high-fiber diets mitigate these effects, allowing horses to engage in more natural behaviours, including reduced stress-associated standing postures [48]. Sweeting et al. [18] found that ponies with free access to hay spent less time standing (19 %) compared to those managed similarly but fed limited amounts of hay (23 %). Similarly, the study by Willard et al. [53] found that feeding concentrates, rather than restricted hay, increased the time spent standing from 45 % to 62 %.

4.3. Activity behaviours and time

The activity of wild horses is strongly influenced by their environment [54]. In this study, horses managed under free conditions spent a significantly higher percentage of time in active behaviours (7.51% ± 0.44 %) compared to those housed indoors (4.49% ± 0.33 %; p < 0.0001). Sociality also played a critical role: horses in groups exhibited increased activity (6.66% ± 0.57 %) compared to isolated individuals (4.58% ± 0.55 %; p = 0.0220). Feeding type further influenced movement, with grazing horses spending more time in locomotion (7.51% ± 0.44 %) compared to hay-fed horses (4.49% ± 0.33 %; p < 0.0001). The ability to move can be severely limited by the physical constraints of stable walls (Management: Indoor). Exercise outside the stable largely depends on the owner's or rider's choices. Locomotion within stalls is generally minimal and rarely measured [55]. Horses kept in confined and restricted environments, without opportunities to interact with other animals and with limited hay availability (2–3 meals per day), spend significantly less time moving compared to wild horses in large grazing areas with their conspecifics [56]. Also, in the study of Raspa et al. [49], locomotion was positively correlated with increased space availability. Both Boyd et al. [29] and Keiper and Keenan [25] found that locomotion decreases during night-time hours, with horses in both studies spending much of the night lying down. Both domestic horses and Camargue horses spend up to 10 % of their time in locomotion. In this context, there may be an inverse correlation between time spent feeding and time spent moving. However, it is important to note that foraging and locomotion are typically classified as mutually exclusive behaviours, particularly when locomotion is defined as directed movement from point A to point B without concurrent ingestion. Some variation in reported locomotion times across studies may reflect differences in how movement and foraging were delineated during behavioural observations, especially in free-ranging conditions [21].

4.4. Factors

This section delves into the primary factors identified in the study—feeding type, sociality, sex, age, size, and management—and examines their distinct impacts on equine time-activity budgets. Each factor is explored in detail to illustrate its role in shaping behavioural patterns, emphasizing how these elements influence welfare outcomes.

4.4.1. Feeding type

This study analysed two feeding types: grazing and hay feeding. The pooled results of the analysed studies are presented and compared in the two histograms in Fig. 6a. Research has shown that horses evolved to consume small portions of fiber-rich food continuously, a behaviour that mirrors their natural diet [27,31]. This feeding habit is best supported when horses are allowed to graze, which not only extends feeding times but also promotes more natural foraging behaviour, significantly enhancing their well-being [32].

Furthermore, the percentage of time horses spent standing varies significantly across studies, potentially due to differing criteria used to define resting states. Despite these differences, Sweeting et al. [18] observed that ponies with unlimited access to hay spent less time standing (19 %) compared to ponies receiving limited amounts of hay (23 %), suggesting that food access also influences resting patterns.

Horses housed in confined spaces without social interaction and with limited access to hay tend to show reduced physical activity compared to wild horses living in large grazing areas with their conspecifics [56].

It is important to note that the quality of hay plays a crucial role in horse nutrition, as hay is often the most commonly used feed. Ensuring the healthiness and palatability of hay is essential to support the horses' overall well-being, as poor-quality hay can lead to reduced intake, digestive issues, or health problems [57].

4.4.2. Sociality

The study examined two sociality conditions: horses kept alone and those managed in groups (Fig. 6b). The study by Auer et al. [3] provides

a detailed exploration of how sociality influences the feeding behaviour of horses, comparing domesticated individuals housed in separate stalls with semi-wild horses. Significant differences emerge in the daily feeding time budget, ranging from 10 % to 66.6 % over 24 h. Horses confined to closed, restricted spaces, deprived of social interaction and with limited access to hay, exhibit reduced physical activity compared to semi-wild horses that benefit from large grazing areas and the company of conspecifics.

Additionally, the presence of companions has a significant impact on resting time: horses rest for longer periods when in a group than when alone, highlighting the importance of social aspects even in the context of rest [45].

4.4.3. Sex

To explain the data shown in Fig. 6c, which compiles information from multiple studies, we can consider how reproductive behaviours, such as young stallions searching for mares, may lead them to cover long distances. Analysis of the studies reveals that females spend more time foraging than males, a difference that can be attributed to the higher nutritional needs of females near the peak of lactation, which requires nearly double the protein and energy intake compared to males [36].

4.4.4. Age

The study analysed two age groups: horses older than three years and those aged one to three years (Fig. 6d). The proportion of time horses spend in a standing position shows significant variation across studies. Generally, adult horses dedicate about 80 % of their resting period to standing, allocating only a small portion of the 24 h day to lying down. In contrast, foals under three months old exhibit a different pattern, spending 70 % to 80 % of their resting time lying down [26–28]. This behaviour is likely linked to developmental needs, as suggested by studies analysing early-life activity patterns [18,30,46].

Notably, the study by Boy and Duncan [26] demonstrated that as foals grow older, they progressively reduce the time spent resting in a lying position, highlighting the importance of age as a determining factor in the distribution of resting time. This pattern is further confirmed by analysing data on lying behaviour (Lying), emphasizing that age significantly influences resting habits: young horses, aged 1 to 3 years, tend to lie down more frequently than adult horses over 3 years old. Consequently, as horses age, they spend more time in a standing position (Standing).

4.4.5. Size

The study compared two size categories: horses and ponies (Fig. 6e). It is believed that adult horses are unable to lie completely in a lateral position due to their weight and the potential respiratory fatigue that may result from maintaining this position for extended periods, as noted by Belling (1990).

This limitation may explain the differences observed in the results between horses and ponies. Fig. 6e clearly shows that ponies spend more time feeding and resting compared to horses. Horses lie completely in a lateral position to achieve REM sleep, an essential part of their rest cycle [58]. However, being prey animals, they typically maintain this vulnerable position for no more than 15 min at a time to reduce exposure to predators. Over a 24 h period, they accumulate around 0.63 h (~38 min) of REM sleep, a relatively short duration compared to humans. To compensate, they adopt other resting postures, such as standing or lying with the head elevated above ground level (commonly seen in sternal recumbency), rather than fully resting the head against the surface. This posture allows for partial rest without entering REM sleep, which typically requires full lateral recumbency, demonstrating an evolutionary strategy that balances rest with the need for vigilance [58].

This phenomenon can be attributed to the behavioural adaptations ponies have developed due to human-driven genetic selection. Ponies are generally smaller in size than horses, which means they have a different metabolism and may require proportionally more food relative to their body size [36]. As a result, they may spend more time feeding to meet their energy requirements. Also, the morphology is different, as variations in head and mouth structure, such as mouth width and mandibular length, influence feeding efficiency and behaviours, with smaller ponies requiring more bites and chews to process forage, as demonstrated in the study by Bordin et al. (2024).

4.4.6. Management

The study compared two management systems: freedom (pasture) and indoor housing (Fig. 6f). The study highlights that keeping horses on pasture ensures longer feeding periods [32]. In contrast, horses fed forage placed on the floor in enclosed environments, such as stalls, tend to consume their food more quickly. Further analyses of "Freedom" (free-range) and "Indoor" (enclosed) management systems, as well as feeding types, indicate that horses in confined environments with rationed hay display greater activity in maintaining a static standing position.

The lack of space for free movement, the inability to interact with other animals, and limited access to forage are factors that significantly reduce the time dedicated to movement, in contrast to wild horses that live in large open spaces and in the company of their conspecifics.

The physical restrictions imposed by stall walls severely limit the horses' ability to move (Management: Indoor). Opportunities for physical exercise outside the stable largely depend on the decisions of the owner or rider. Locomotion within stalls is generally minimal and rarely measured [55]. Moreover, research on horse welfare in semi-extensive systems highlights similar challenges related to limited locomotion in stables. For example, Raspa et al. [59] noted that while Catria horses kept in stables during winter had access to outdoor paddocks, their movement remained restricted compared to pasture systems. This reduced movement, combined with inadequate dietary management in some cases, raises concerns about maintaining optimal welfare standards for horses housed in confined spaces during colder seasons.

5. Limits of the study

This study presents certain limitations that must be considered for the interpretation of the findings. The analysis draws upon a relatively modest dataset comprising 14 studies conducted between 1979 and 2020, which may not comprehensively reflect the diversity of equine management practices or populations across different contexts. Furthermore, inconsistencies in the methodologies employed to define and quantify behavioural metrics among the included studies could introduce variability in the results; the behavioural data extracted from the literature may have been derived using different observation methods, such as scan sampling, continuous sampling, video observations, or direct observations. The absence of granular data on critical environmental factors, such as pasture quality and climatic conditions, further constrains the scope of the conclusions. Additionally, while advanced statistical approaches were applied, the intricate interplay of variables like age, sex, and social dynamics could not be entirely disentangled, potentially obscuring combined effects. These considerations underscore the need for future research that incorporates a broader dataset, integrates environmental variables, and explores the synergistic influences of multiple factors on equine behaviour and welfare. Finally, it is also worth noting that most included studies (12 out of 14) originated from the Northern Hemisphere. Although two studies were conducted in Australia, the overall geographical distribution remains unbalanced, potentially limiting the generalisability of the findings to global horse populations and diverse management systems, especially those in tropical or South American contexts.

6. Future research directions

Expanding the scope of research to encompass a broader spectrum of equine populations across diverse geographic regions and management

paradigms is imperative for enhancing the generalizability of findings. The integration of environmental variables, such as climatic influences and pasture quality, holds the potential to yield a more holistic comprehension of their effects on equine behaviour. Moreover, delving into the interplay of factors like age, sex, and social dynamics could illuminate their synergistic impacts on time-activity budgets.

In this context, the adoption of advanced technologies, such as GPS tracking systems, accelerometers, and environmental sensors, represents a cornerstone of Precision Livestock Farming (PLF) applied to horses [60]. This emerging field provides innovative tools for real-time behavioural and welfare monitoring, enabling the collection of highly precise and dynamic data. For instance, wearable sensors can monitor not only movements but also physiological parameters like heart rate and body temperature, offering direct indicators of stress or discomfort [61]. PLF also supports a proactive and personalized approach to equine management by leveraging large datasets to identify abnormal behavioural patterns or early signs of health issues. Camera-based technologies and computer vision algorithms contribute to monitoring social interactions, while geolocation systems allow for analysing spatial usage and preferences for specific environments [62]. Integrating these technologies with digital management platforms consolidates information from various sources, facilitating data-driven decision-making and enhancing equine welfare and productivity.

7. Conclusion

This study underscores the pivotal role of time-activity budgets as a robust metric for assessing equine welfare comprehensively. Through meta-analysis of 14 studies, significant differences were identified in key behaviours (feeding, lying, standing, and activity) based on management practices, sociality, age, body size, and diet. By advocating for environments that closely mimic the natural conditions of horses, it provides actionable recommendations for optimizing management practices. Ongoing research remains indispensable to refine our understanding further and establish standardized frameworks for equine welfare. Bridging the divide between empirical knowledge and practical implementation, these endeavours will foster the development of ethical and sustainable management strategies, ensuring the global prioritization of equine well-being.

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Ethical statement

This study does not present any ethical concerns.

CRediT authorship contribution statement

M. Lamanna: Writing – original draft, Visualization, Methodology, Investigation. **G. Buonaiuto:** Writing – review & editing, Formal analysis. **R. Colleluori:** Writing – review & editing, Methodology. **F. Raspa:** Writing – review & editing, Validation. **E. Valle:** Writing – review & editing. **D. Cavallini:** Supervision, Software, Project administration, Data curation, Conceptualization.

Declaration of competing interest

None of the authors have any financial or personal connections that could unfairly influence or bias the content of the paper.

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