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Validation of a noseband pressure sensor algorithm as a tool for evaluation of feeding behaviour in dairy Mediterranean buffalo (*Bubalus Bubalis*)

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Abstract

This research communication addresses the goal of validating an algorithm to monitor natural occurrence of feeding behaviours in dairy Mediterranean buffalo based on the output of a noseband pressure sensor (RumiWatch®, halter). Several characteristics of the feeding behaviour were detected with a very high (*ruminating boluses*), high (*chews per bolus*) and moderate degree of correlation (*chews per minute*) with video analyses (gold standard). All of them were associated with a low mean difference with the gold standard, and the mean relative measurement error ranged between low (*ruminating boluses*) and moderate (*chews per bolus* and *chews per minute*). The proportion of correctly detected events for the variables *rumination* and *eating time* was 98 and 99%, respectively. The collection of data and subsequent evaluation of the parameters investigated may provide objective information on Mediterranean Buffalo behaviours allowing for reliable studies of the animal welfare in this ruminant in the future.

The impact of the use of sensor devices for the automatic detection of pathological and management-relevant behavioural changes is increasing in ruminant management (Ruuska *et al*., 2016). Indeed, data from such instruments can provide effective management support in various types of farming systems, allowing for the avoidance of a labour intensive and potentially error-prone direct observation of the livestock (Zehner *et al*., 2017). In cattle, rumination and chewing activities have been identified as important parameters to assess the adequate composition of a diet, provide meaningful information on calving time, subclinical diseases or health disorders (Soriani *et al*., 2012; Fadul *et al*., 2017). Unfortunately, Mediterranean buffalo (MB) have been considered similar to cows for a long time and, as a consequence, poor scientific knowledge on these aspects are present in literature (Guccione *et al*., 2017*a*). Concepts like prevention of diseases (Guccione *et al*., 2017*b*) or animal welfare received attention only recently (Guccione *et al*., 2016; Cagnardi *et al*., 2017). Even more, the use of automatic devices for monitoring behaviour seems to be far from its practical application in MB; the first validation of a pedometer algorithm in MB, previously validated for cows for the evaluation of locomotor behaviour, has been published only recently (D'Andrea *et al*., 2017). Considering these premises, the goal of the current investigation was to validate an algorithm of the RumiWatch® noseband pressure sensor in MB by comparing some feeding behaviours as determined by video analysis (gold standard) with the output of the pressure sensors included in the RumiWatch® halter.

Materials and methods

The current investigation was carried out on 2 groups of 5 healthy primiparous dairy MB each (total of 10 animals), between May and October 2015. All MB were between 28 and 31 month old (mean = 29.2 ± 1.13 SD) and reared in the same breeding farm located in Southern Italy. MB were continuously housed in a free stall and did not have access to pasture for grazing. Each animal was submitted to a complete clinical examination, in particular to exclude the presence of oral, maxillofacial, or dental diseases, before the halter device was applied (RumiWatch®, ITIN + HOCH GmbH, Switzerland). All procedures performed in this study received an institutional approval by the Ethical Animal Care and Use Committee of University of Naples 'Federico II'; moreover, the farmer's consent was received prior to the start of the study. Each animal enrolled was unequivocally identified for an easy recognition during the video analysis; once marked and equipped with the halters, MBs were moved

Table 1. Overall number of events, Cohen's κ coefficient, average mean and standard deviation observed in 10 primiparous dairy Mediterranean buffaloes

Variable (units)	Total validation time	K^3	Events detected at VRA[4]	Events detected at RWh[5]	Average (SD[6]) VRA	Average (SD) RWh
Rumination time (s[1])	12 000 s	1	12 000	11 762.22	1200(±0.00)	1176.22(±31.58)
Eating time (s)	12 000 s	1	12 000	11 848	1200(±0.00)	1184.80(±31.10)
Ruminating boluses (n^2)	12 000 s	0.99	176	173	17.630(±3.20)	17.30(±3.40)
Chew per bolus (*n*)	12 000 s	0.99	593	568	59.30(±9.82)	56.80(±10.12)
Chew per minute (*n*)	12 000 s	1	736	713	73.60(±3.93)	71.33(±7.80)

All data were generated by the RumiWatch® halters and compared with those obtained from video recording analyses (gold standard).
1=seconds; 2=number; 3=Cohen's κ coefficient, interpreted as follows: values ≤0 as indicating no agreement, 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement; 4=Video recording analysis; 5=RumiWatch® halter; 6=standard deviation.

back to their pen shared with the rest of the herd (another 35 MB). The hardware used was the RumiWatch® halter (RWh) already validated for cows by Ruuska *et al.* (2016). The device was characterized by a noseband pressure sensor, a data logger showing in real-time the activities performed by the animals, and evaluation software. The noseband sensor consists of a glycol-filled silicone pressure tube moulded to the back of the MB's nose with a built-in pressure sensor inserted in the casing of a fully adjustable polyethylene halter (Ruuska *et al.*, 2016). During the validation trial, the accuracy of the device to detect the occurrence of eating and rumination behaviour in primiparous MB was performed comparing RumiWatch® outputs with observational data originating from the video recordings analysis (VRA, gold standard). The following behaviours were validated: *rumination time*, *eating time*, *ruminating boluses*, *chews per bolus* and *chews per minute* as defined in online Supplementary Table Sa. Halters were attached to the animals for a period of 2.5 d (overall monitoring phase), of which the first 2 d were considered as adaptation phase (data acquired but not used for the analysis) and 0.5 d as data acquisition phase (data used for the analysis); during the acquisition phase, each activity validated was videotaped for an overall period of 1200 s, using a hand-held digital video camera (Nikon d3200, Nikon Corporation, Japan). At the end of each monitoring phase, all data recorded were transferred from the RWh to the computer by means of an USB cable (supplied by the manufacturer) and stored using RumiWatch® Manager 2 dedicated software (ITIN + HOCH, Liestal, Switzerland). Raw data were converted from '.RAW' filename extension (automatically generated by the software) to '.CSV' filename extension by means of the RumiWatch® Converter (dedicated software, ITIN + HOCH, Liestal, Switzerland) for statistical analysis. Finally, each feeding behaviour considered was determined 3 times by VRA by the same investigator blinded as to the data output of the RWh. The mean values obtained by VRA were compared with the data generated by the devices. All parameters were analysed by standard descriptive statistics as described by D'Andrea *et al.*, (2017). The different behaviours were analysed by means of proportion and 95% confidence intervals (discrete data), a mean relative measurement error (RME) and Spearman's rank correlation test (continuous data) as described by Alsaaod *et al.* (2015). For discrete variables, sensitivity (Se) was also assessed. Moreover, for continuous variables, Bland-Altman analysis were used to evaluate differences observed between the output of VRA and RWh and a potential bias of the RWh, as well as a Cohen's κ coefficient (*K*) to measure reliability of the agreement of the VRAs done by the same investigator (D'Andrea *et al.*, 2017). A dedicated statistical software was used (SPSS, Version 17.0, Chicago, IL), and probabilities <0.05 were considered significant.

Results and discussion

Descriptive data and Cohen's κ coefficient results are shown in Table 1. Results regarding discrete and continuous variables are reported in detail in Table 2. Bland-Altman plots comparing RWh outputs and VRA are reported in online Supplementary Fig. Sa. To the best of the authors' knowledge, this is the first time that a noseband sensor has been validated in MB. During the investigation, two main weak points were found: one related to the dimensions of the harness and one related to a specific MB's behaviour observed. The first concerned the difficulty to adapt the harness to the MB's head since these ruminants have bigger head dimensions than cows (online Supplementary Fig. Sb). As a consequence, it has not been possible for the authors to validate the device on adult animals but only on primiparous buffalo with smaller heads, similar to those of cows. The second problem was related to MB's habit to place their mouth deep into the total mix ration, impeding a correct identification of the jaw movements during eating. As a result, during the validation process, it was not possible to consider the parameter *total eating jaw movements*, regularly investigated in cows (Zehner *et al.*, 2017). Therefore, the present study design allowed to verify the reliability of only 5 activities as reported in Tables 1 and 2.

Regarding the detection of the events *rumination time* and *eating time*, the device was very accurate in MB (Table 2), as also shown in previous studies performed in the cow (Ruuska *et al.*, 2016; Zehner *et al.*, 2017). The proportions showed that the total *rumination time* ($P = 0.98$) and *eating time* ($P = 0.99$) measured by RWh were very similar to the values detected by VRA (Table 2). The reliability of these important parameters may in the future allow the development of an objective understanding of MB's normal feeding behaviour and of the welfare by means of (i) evaluation of the dietary effects on digestive function and performance, as well as (ii) providing information on the diurnal/nocturnal patterns to identifying deviations that may be used for detection of health impairments.

Concerning the *number of bolus*, a low mean RME (4.34%) and Bland-Altman bias (−0.3) as well as a very high correlation ($r_s = 0.93$) between the data obtained was observed (Table 2, online Supplementary File Fig. Sa). The findings confirmed, both in MBs and in cows ($r_s = 0.97$, Zehner *et al.*, 2017; $r = 0.90$; Kröger *et al.*, 2016), a reliable correlation between visually and automatically obtained measurements. Finally, regarding the variables *chews per bolus* and *chews per minutes*, high ($r_s = 0.69$) and moderate ($r_s =$

Table 2. Counts, proportions, Se, correlations, relative measurement errors and Bland–Altman analysis of the variables validated in 10 primiparous dairy Mediterranean buffaloes

				95% CI[4] of *P*				
Variables	VRA[1]	RWh[2]	p[3]	Lower	Upper	TP[5]	FN[6]	Se[7] (%)
Rumination time	11 762.22	12 000	0.98	0.96	0.99	11 762.22	237.88	0.98
Eating time	11 848	12 000	0.99	0.97	1.000	11 848	152	0.99

				Range value		95% CI of RME		B-A[11]		95% CI of B-A	
Variables	r_s[8]	RME[9] (%)	SD[10]	Lower	Upper	Lower	Upper	(bias)	SD	Lower	Upper
Ruminating boluses	0.93	4.34	4.14	4.55	7.14	1.38	7.30	−0.3 (*n*)	0.95	−0.98	0.38[a]
Chews per bolus	0.69	10.26	9.02	1.61	33.90	3.81	16.71	2.5 (*n*)	7.97	−3.21	8.21[a]
Chews per minute	0.53	9.22	5.82	2.16	23.86	5.61	12.83	−2.26 (*n*)	8.05	−8.02	3.49[a]

All data were generated by the RumiWatch® halter and compared with those obtained from video recording analyses (gold standard).
1=Video recording analysis; 2=RumiWatch® halter; 3=proportion; 4=confidence interval (95%); 5=true positive values; 6=false negative value; 7=sensitivity=true positive/(true positive+false negative); 8=Spearman's correlation coefficient: $r_s \geq 0.9$ were scored as very high; r_s between 0.89 and 0.68 as high; r_s between 0.67 and 0.36 as moderate, and $r_s \leq 0.35$ as weak; 9=mean relative measurement error=(100/video-recording observation) × absolute value (video-recording observation—RumiWatch® observation); 10=standard deviation; 11=Bland–Altman analysis used to evaluate differences observed between the overall estimates output of the VRA and RWh and a potential bias of the RWh.
[a]One value (10.0%) of each parameter is outside the interval of confidence (see also fig. Sa-supplementary file).

0.53) correlations were found, respectively, although both showed moderate mean values of RME (10.26 and 9.22%, respectively; Table 2). The latter values were considerably lower than those found for cows; indeed in a recent study, these parameters reached correlation values of $r = 0.88$ (*chews per bolus*) and $r = 0.81$ (*chews per minutes*) (Kröger *et al.*, 2016). The difference observed as well as the moderate RME (Table 2, online Supplementary Fig. Sa) may be due to technical reasons, probably related to the proportion between dimensions of MB's heads and the halters. Despite the use of primiparous MB with smaller heads, nevertheless the noseband sensor could not be ideally fitted to the nose with the potential consequence that the mouth movements did not adequately stimulate the sensors. In the future, the company may easily approach this weak point by means of a better adaptation of the instrument's diameters to the MB, potentially improving, as a consequence, the performance of the device in this ruminant.

In conclusion, the halter's algorithm allows an accurate detection of several feeding behaviours in Mediterranean buffalo. The accuracy of the RWh may be improved by manufacturing a halter that fits better to the dimensions of the MB's head. Although not all variables validated for cows have been analysed here, the evaluation of the parameters investigated may provide objective information on MB's behaviours promoting reliable studies of the normal feeding behaviour and the welfare also in this ruminant.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0022029919000074.

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